A FINAL REPORT

Movement of Kemp's ridley and loggerhead sea turtles off the Georgia - Florida coast

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EXECUTIVE SUMMARY

Telemetry was used to monitor movement and behavior of six sea turtles. Two Kemp's ridley and three loggerhead sea turtles were captured in Brunswick Channel, Georgia, equipped with radio and sonic transmitters, and released at the capture location. A satellite transmitter was placed on a Kemp's ridley captured and released in St. Mary's Channel.

1. Radio-tagged subadult Kemp's ridleys moved south from Brunswick Channel, Georgia along the Florida coast a distance of 120 and 202 km during 41 and 29 days, respectively.

2. A satellite-tagged adult female Kemp's ridley moved 267 km south from the Georgia-Florida border to Cape Canaveral, Florida during the first month at large, and overwintered in Atlantic coastal waters within 111 km south of that location from mid-November to mid-March.

3. After the second day at large, tagged sea turtles were not found in channels, although two Kemp's Ridleys together spent at least seven days and perhaps eleven or more days within 6 km of St. Mary's Channel.

4. Kemp's ridleys were not observed in water temperatures below 18°C, although continuous temperature monitoring was not

conducted.

5. Duration of night submergence events was significantly longer than those during the day for only one of two Kemp's Ridley sea turtles monitored.

6. All 50 night dives monitored were longer than 10 minutes in duration.

INTRODUCTION

The U.S. Army Corps of Engineers (COE) has a Congressional mandate to maintain navigability of shipping lanes throughout the United States. Hopper dredges are often used in maintenance dredging of many coastal channels. Unfortunately, hopper dredging activities on the Atlantic coast can result in mortality of endangered and threatened species of sea turtles by entrainment through the draghead (Slay and Richardson, 1988). Under the Endangered Species Act, the National Marine Fisheries Service (NMFS) received a Congressional mandate to protect sea turtles. NMFS restricted the use of hopper dredges on the Atlantic coast to the months of December through March, when sea turtles were thought not to inhabit these channels (Dr. T. Henwood, NMFS Southeast Regional Office, personal communications). One exception was Cape Canaveral, Florida where sea turtles were known to occur in the channel virtually year round. However, existing data are insufficient to permit relaxation of restrictions on use of hopper dredges.

Limited information is available on seasonal distribution and movement of Kemp's ridley (*Lepidochelys kempi*) and loggerhead sea turtles (*Caretta*) along the Atlantic coast of the United States (Stoneburner, 1982; Kemmerer et al., 1983; Henwood, 1987; Henwood and Ogren, 1987; Standora, et al., 1989; Byles and Dodd, 1989; Keinath, et al., 1989; Murphy and Hopkins-Murphy, 1990; Renaud, 1990; Standora, et al., 1990). The COE South Atlantic

District conducted periodic trawling surveys in selected east coast channels for several years to provide NMFS with data pertaining to the seasonal distribution and abundance of sea turtles. While loggerhead sea turtles were frequently captured during COE trawling activities of October 1991, the capture of three Kemp's ridleys provided a unique opportunity to study the behavior of sea turtles in and around channels. The results of this investigation are reported herein.

Project objectives are listed in descending order of priority.

1. Determine movement of Kemp's ridley sea turtles captured and released in Atlantic coast ship channels, and document associations with navigational channels.
2. Document Kemp's ridley surface and diving behavior.
3. Investigate movement of loggerhead sea turtles captured and released in Atlantic coast ship channels, and document associations with navigational channels.
4. Document loggerhead surface and diving behavior.

MATERIALS AND METHODS

Sea turtle capture:

The University of Georgia's R/V Bulldog, dragging two shrimp trawls each with a 18.3 m headrope and 20.3 cm stretch mesh, collected two subadult Kemp's ridley and three loggerhead sea turtles during repetitive 30 minute tows in the Brunswick Channel of Georgia. One additional Kemp's ridley was captured in St. Mary's Channel approximately 11 km offshore. All sea turtles were held in separate compartments of outdoor tanks at the Georgia Department of Natural Resources in Brunswick for four to five days while awaiting tag attachment and subsequent release at the capture location.

Transmitter attachment:

Radio, sonic, and depth-sensitive sonic transmitters were attached to the two smallest Kemp's ridleys whereas loggerheads carried only radio and depth-sensitive tags (Table 1). Sea turtles were removed from water and the carapace dried prior to attaching radio transmitters measuring 3.8 x 3.3 x 6.1 cm and weighing 180 g. A two-part epoxy mix was used to build a flat platform on top of the anterior portion of the pronounced dorsal ridge of Kemp's ridleys. The epoxy mix was then used to secure the bottom of the radio transmitter to the top of the platform. Since loggerheads lacked an angular dorsal ridge, construction of a platform was unnecessary for this species. Two layers of epoxy resin and cloth were then applied across the longitudinal and cross sectional axes of the transmitter to secure the unit to the carapace.

Depth-sensitive sonic transmitters measuring 1.9 x 8.1 cm and weighing 34 g were cylindrically shaped. One device was attached to each sea turtle by tightly lacing metal wire through one end of the sonic tag and through a hole drilled in the most posterior marginal scute. The other end of the tag trailed behind the sea turtle. The two Kemp's ridley sea turtles were equipped with a second sonic transmitter (not depth-sensitive) using two threaded metal nuts and bolts inserted through the transmitter and through holes drilled in lateral, marginal scutes.

The Kemp's ridley captured in St. Mary's Channel was of sufficient size (61 cm SCL) to carry an 817 g satellite transmitter (3.8 x 10.8 x 14.0 cm) which provided information on location, tag temperature, mean submergence duration, duration of last submergence before a transmission, and number of dives. Only data collected during the 12 h period preceding each transmission were received. The device was programmed to transmit continuously for 10 h, turn itself off for 50 h, and repeat this sequence for the duration of its battery life. The operating life of this unit was estimated at 18 months. Satellite tag attachment procedures were identical to those used for the radio transmitters.

Tracking equipment and procedures:

The radio tracking system included a directional, 5 element Yagi antenna and an omnidirectional antenna wired to a Telonics TR2/TS1 receiver/scanner. A directional H-antenna was sometimes substituted for the Yagi antenna. The five radio tags transmitted on separate frequencies in the 165 MHz band (Table 1). All radio tags were tested prior to attachment to experimental animals to verify transmittance frequency.

Directional hydrophones and receivers with adjustable frequency modulation were used to monitor sonic signals at distances up to 1 km. Depth-sensitive and standard sonic transmitters, produced by Sonotronics, were tested to verify the transmittance frequency prior to attachment to experimental animals. A Sonotronics digital receiver (USR-SB) with directional hydrophone was used to monitor signals from depth-sensitive tags in the 68-80 kHz range, and a Dukane receiver (N30A5B) with directional hydrophone was used for standard sonic tags transmitting at a frequency of 32.7 kHz (each tag had a unique pulse interval for identification).

Data collection included time of surfacing and submergence events, latitude, longitude, and compass bearing to the signal. Locations were determined using a Global Positioning System that utilized satellites to compute latitude and longitude. LORAN C provided a backup. Surface and bottom water temperature and salinity were collected opportunistically (Appendix 1). Satellite imagery collected by an AVHRR (advanced very high resolution radiometer) sensor aboard the NOAA 11 polar orbiting satellite provided additional data on sea surface temperature.

Initially, tracking was conducted from contract vessels which enabled personnel to record visual sightings of the experimental animal when it surfaced, and provided a suitable workplace during relatively rough seas. However, contract vessels frequently could not venture into shallow waters adjacent to the Brunswick Channel due to the deep draft of the vessel. This caused difficulty in monitoring the sea turtles' southward movements along Jekyll and Cumberland Islands. The problem was solved about two weeks into the study, when a 7.6 m vessel purchased and outfitted for sea turtle tracking became available. Shipboard tracking was generally conducted during daylight hours.

At several times during the 41-day study period, high seas prevented offshore tracking. During these intervals, sea turtles were monitored from land using radio telemetry deployed at a variety of locations including piers, beaches, lighthouses, and condominiums.

When sea turtles became separated by large distances during the third week of the study, a second tracking team was used to operate a portable radio monitoring station deployed from a van. This team conducted land-based monitoring at a variety of locations along the east Florida coast from Amelia Island to Daytona Beach.

When trackers were in jeopardy of losing contact with a sea turtle, determination of the bearing to the radio signal took precedence over precisely noting the time of surfacing. When this occurred and only an approximate surface time was recorded, these data were not included in the analysis of surface and submergence duration.

Positions of sea turtles were plotted on maps to determine movements. When visual or sonic contact was made with a tagged sea turtle, sea turtle location was plotted at the latitude and longitude of the tracking vessel because of the close proximity between sea turtle and tracker. During radio monitoring from positions on land, bearings taken with a handheld compass from a directional radio antenna to the sea turtle were plotted and positions determined using a computer program. Although positions obtained from this procedure were less accurate than positions from visual sightings and sonic signals, bearings from radio telemetry alone still provided valuable information on sea turtle location. Although most land-based tracking occurred during the day, some nighttime monitoring and continuous 24 h monitoring sessions were conducted. Nearly all shipboard tracking occurred during the day.

In previous unpublished studies conducted by the authors, turtles experienced an acclimation period before normal behavior patterns are re-established after release. Consequently, the first two days of data were deleted prior to analysis of diving behavior using t-tests with 99% ($p<0.01$) confidence limits.

Eight aerial overflights with fixed wing aircraft were conducted to relocate sea turtles using directional radio antennas secured to the wing struts of the plane (Figures 1-8). Flights were usually three hours in duration at an airspeed of approximately 167 km/h and an altitude of 270-300 m. Due to technical limitations of equipment and relatively short surface events which made it difficult to ensure accuracy of bearings determined during aerial overflights, results from aerial surveys were only used to locate the general area where subsequent telemetry effort should be directed on land and.

Study Area:

The study area traversed by tagged sea turtles included the Atlantic coast of the U.S. extending south from St. Simon's Island, Georgia to Vero Beach, Florida. Channels or passes were located at St. Simon's Sound, St. Andrew Sound, Fort George Inlet, St. Mary's Entrance, Nassau Sound, Mayport, St. Augustine, Matanzas Inlet, Ponce de Leon Inlet, Cape Canaveral, and Sebastian. Of these, Brunswick, St. Mary's, and Cape Canaveral were periodically maintained by hopper dredges. A brief description of the channels follows.

Brunswick, St. Mary's, Mayport, and Cape Canaveral Channels carry large, oceangoing ship traffic and the last three support U.S. Naval bases (nuclear submarine bases are located at Cape Canaveral and inside St. Mary's at Kings Bay on the Intracoastal Waterway). Consequently, these three channels are relatively deep (10-20 m with occasional holes as deep as 30 m) and well maintained. All except Brunswick have at least one jetty extending from shore. In contrast, the remaining channels and inlets are relatively shallow (1-6 m except for St. Andrew's Sound which is 6-18 m) and carry primarily small boat traffic.

RESULTS

Two subadult Kemp's ridley sea turtles captured in Brunswick Channel measured 38 and 42 cm straight carapace length (SCL) and three loggerhead sea turtles measured 59, 61, and 89 cm SCL (Table 1). One adult Kemp's ridley sea turtle captured in St. Mary's Channel measured 61 cm SCL. Results of blood samples taken from the Kemp's ridleys by Jim Richardson were unavailable at the time of writing. Using tail length as a sex determining characteristic for adult turtles, one Kemp's ridley was female and one loggerhead was male.

Movement and Migration:

<u>Kemp's Ridley #1</u>. After release near its capture location between Jekyll and St. Simon's Islands in the Brunswick Channel, Kemp's Ridley #1 moved into the Atlantic Ocean (Figure 9). Summaries of locations for this subadult sea turtle during each 10 day period after release are shown in Figures 10-13. During the first two days after release, this subadult Kemp's ridley was found either in the Brunswick Channel or within approximately 2 km of the channel and not more than 5 km offshore. High seas and a malfunctioning radio receiver hindered data collection during the first 10 days. During 11-20 days after release, Kemp's Ridley #1 was located approximately 37-46 km south of the release site within a few kilometers both north and south of St. Mary's Channel. From 21-30 days at large, the sea turtle was found in

an area extending from St Mary's Channel to about 11 km south, despite the passage of an offshore hurricane which resulted in very strong southerly currents. During the final 10 days of monitoring, Kemp's Ridley #1 moved further south to a location approximately half the distance between Jacksonville and St. Augustine, Florida. This sea turtle traveled 120 km south during 41 days at large. Visual sightings and sonic telemetry always placed Kemp's Ridley #1 within 16 km of shore in depths less than 20 m while triangulation located the sea turtle as far as 27 km offshore where maximum water depths were 18-21 m.

<u>Kemp's Ridley #2</u>. This subadult sea turtle was captured and released near the same location in the Brunswick Channel as Kemp's Ridley #1 (Figure 14). Summaries of locations for Kemp's Ridley #2 during each 10 day period after release are shown in Figures 15-17. During the first day after release, the sea turtle was observed in the channel moving west into the sound. However, Kemp's Ridley #2 reversed its course and moved into the Atlantic Ocean where triangulation of radio bearings plotted it off Cumberland Island two days later. During 11-20 days at large, the sea turtle was found in areas from the southern end of Cumberland Island to a few kilometers south of St. Mary's Channel. During the subsequent 10 day tracking period, Kemp's Ridley #2 moved southward much more rapidly than Kemp's Ridley #1. This movement began before an offshore hurricane brought high seas and a strong, southerly current, and continued until

after the high winds of 29 October had subsided. Kemp's Ridley #2 traveled more than 46 km from 25-29 October, and an additional 28 km by 31 October when wind and seas had calmed. This contrasts with Kemp's Ridley #1 which showed little southerly movement during the same period. Kemp's Ridley #2 then traveled north approximately 28 km during the next three days. No further radio transmissions were received after 4 November, 1991. During the 29 day tracking period, this sea turtle traveled 202 km south to approximately Daytona Beach, Florida. Kemp's Ridley #2 was always found within 6 km of shore in water depths less than 18 m based on visual sightings and sonic signals. Triangulation of radio bearings placed Kemp's Ridley #2 as far as 29 km offshore where water depth was estimated at less than 24 m.

Kemp's Ridley #3. Preliminary results of the movement of this female adult Kemp's ridley equipped with a satellite transmitter showed much more rapid southerly movement than the two subadult Kemp's ridleys discussed above. By the end of the first month after release, Kemp's Ridley #3 traveled 267 km to Cape Canaveral, Florida (Figure 18). From mid-November through mid-March, the sea turtle overwintered in the Atlantic Ocean within about 37 km of the coast from Cape Canaveral to just north of Stuart, Florida. Northward migration began in mid-March. Between March 18 and April 20, 1992, Ridley #3 traveled from south of Cape Canaveral northward to Jacksonville, Florida, a distance of approximately 330 km.

The role of water temperature was analyzed in relation to sea turtle movement. Between 14 and 17 November, Kemp's Ridley #3 moved east-northeast from a location approximately 28 km offshore Cape Canaveral to a new location 80 km offshore. Analysis of satellite imagery data depicting sea surface temperature showed Kemp's Ridley #3 in water temperatures between 21 and 23°C on 13 October and 23 October as it moved south along the Florida coast. On 14 November, sea surface temperature at the sea turtle's approximate location was only 18°C. By 17 November, the sea turtle had moved 80 km into the Atlantic where temperatures were in excess of 25°C, actually registering off the temperature scale used for this type of satellite imagery. Approximate water depth for this location as determined from NOAA Chart 411 was 293-750 km. By 17 December, the next occasion when both a clear satellite image and an accurate sea turtle location occurred on the same day, Kemp's Ridley #3 had returned from the Gulf Stream to within 20 km of shore where the water temperature had increased to 21-22°C. None of the three tagged Kemp's ridleys were observed in water temperature below 18°C, although continuous monitoring of water temperature throughout the entire study area was not conducted (Appendix 1).

<u>Loggerhead #1</u>. Although the primary objective focused on Kemp's ridley movements and behavior, transmitter frequencies for the loggerheads were monitored throughout the study. Seven days after release, the adult male loggerhead was located off the

northern coast of Amelia Island near St. Mary's Channel less than 11 km offshore where water depth was approximately 15 m (Figures 19 and 20). During the next two weeks, Loggerhead #1 was never found more than 9 km south of St. Mary's Channel (Figure 21). Insufficient data were collected to permit a detailed study of subsequent movements and behavior.

Loggerheads #2 and #3. A concerted effort was made to relocate the two loggerheads using radio receivers from aircraft (Figures 1-8) and atop the lighthouse on St. Simon's Island. Reception range obtained during aerial overflights was probably well over 37 km and was primarily limited by signal strength of the radio transmitter. On 14 October, the flight path extended 59 km north of Brunswick Channel and 19 km offshore while another aerial survey on 8 November stretched from Cumberland Island south to St. Augustine and parallel to shore at a distance of approximately 46 km. On 30 October, a radio receiver was monitored for two hours from atop St. Simon's Lighthouse at a height of approximately 46 m. With the exception of the release day, the two subadult loggerheads were never located with telemetry and their movements were unknown.

Kemp's Ridley Behavior:

Duration of surfacing and submergence events varied between and within individuals. Duration of surfacings ranged from 1 second to 11.8 minutes for Kemp's Ridley #1 and from 1 second to

14.3 minutes for Kemp's Ridley #2. Mean duration of surfacing and submergence events were plotted for each hour of the day (Figures 22-24). Daylight hours extended from approximately 0630-1800 during the study. Mean surfacing times were brief in comparison to submergence times for both sea turtles no matter what the hour. However, Kemp's Ridley #2 showed much higher mean submergence durations, especially at night. No other trends relative to time of day were apparent (Figures 22 and 23). When the data from the two sea turtles were combined (Figure 24), a tendency toward shorter mean submergence duration during the day and longer duration at night was indicated.

Diurnal differences were further investigated by plotting the percentage of dives by submergence duration (Figures 25 and 26). During the day, approximately 20% of submergences for both Kemp's ridleys were less than or equal to 1 minute in length. However, less than 1% of Kemp's Ridley #1's day dives were between 1-10 minutes in duration compared with 55% for Kemp's Ridley #2. In contrast, 23% of day dives for Kemp's Ridley #1 were in the 30-40 minute range. Kemp's Ridley #1 also made more day submergences with durations exceeding 20 minutes (78%) compared with 19% for Kemp's Ridley #2.

Results were quite different at night. Although Figure 26 includes only 40 and 10 night dives, respectively, for Kemp's Ridleys #1 and #2, no recorded submergences were less than 10 minutes in duration. Kemp's Ridley #1 still showed the highest percentage of dives (30%) in the 30-40 minute category, while 70%

of Kemp's Ridley #2's dives measured 90-120 minutes. Although these durations may seem exceptionally long for Kemp's ridleys, simultaneous radio, sonic, and visual verification attest to the reality of these long submergence events.

Mean duration of surface and submergence events was also analyzed diurnally. Mean duration of day and night surface intervals was not significantly different for Kemp's Ridley #1 (1.8 minutes during the day and 1.9 minutes at night) or Kemp's Ridley #2 (1.0 minute during the day and 1.8 minutes at night; Table 2, Figure 27). Mean submergence duration was significantly longer at night for Kemp's Ridley #2 (77.3 vs 13.7 minutes) and for both Kemp's Ridleys #1 and #2 combined (45.2 vs 24.9 minutes), but not for Kemp's Ridley #1 (37.2 vs 32.1 minutes; (Figure 28). Overall, radio tagged Kemp's ridleys were submerged during 95% of the time monitored. Submergence time varied little between day and night, ranging from 94.6% to 95.2%, respectively, for Kemp's Ridley #1 and 93.0% to 97.8%, respectively, for Kemp's Ridley #2.

Analysis of surface and diving data collected from the satellite transmitter for Kemp's Ridley #3 will be conducted at the conclusion of the satellite tracking study.

DISCUSSION

Except during the first two days after release, neither radio-tagged Kemp's ridley was observed in a channel. On one occasion, sonic telemetry showed Kemp's Ridley #1 moved north directly toward St. Mary's Channel and turned sharply shoreward to approach the south jetty without actually surfacing in the channel. However, based on the proximity of sea turtles to shore and verified locations immediately north and south of the channel, Kemp's Ridley #1 probably crossed the channel at least twice and Kemp's Ridley #2 at least once. The only alternative, that Kemp's ridleys traveled 20 km offshore and circumvented the channel, is extremely unlikely. Visual and sonic telemetry placed Kemp's Ridley #1 within 6 km of St. Mary's Channel on six days and Kemp's Ridley #2 on three days. On five other days, plots of radio bearings placed Kemp's Ridley #1 on a line intersecting the channel. Using sonic telemetry, Loggerhead #1 was found 4 km from St. Mary's Channel on one occasion. In addition, radio triangulation once placed Kemp's Ridley #2 approximately 2 km from St. Augustine Inlet.

Despite intensive efforts, Loggerheads #2 and #3 were not located after release day. Since radio and sonic transmitters were securely attached to these sea turtles, it is highly improbable that the transmitters detached the second day after release. Although all transmitters functioned properly immediately after release, failure of transmitters cannot be ruled out. Alternatively, the two loggerheads may have simply moved offshore out of range of radio receivers or were submerged when surveying aircraft passed their offshore location. Stoneburner (1982) identified offshore sea turtle habitat (hard bottom, live reef, wrecks) 45 km east of Cumberland Island which were utilized in summer by internesting female loggerheads. He also tracked postnesting female loggerheads 80 km offshore Ossabaw Island, north of Brunswick.

It is not known how long the experimental sea turtles inhabited the channels prior to capture, nor is it known if the sea turtles were already migrating south. Nevertheless, the three Kemp's ridleys and one loggerhead that were successfully monitored moved south out of the channels within two days after release despite the occurrence of sea turtles in the channels as shown by trawl captures within the next thirty days (Nelson). Although there is not yet a clear explanation for this behavior, several alternatives are apparent. Since seasonal migration of Kemp's ridleys in the Atlantic is documented (Henwood and Ogren, 1987), the study animals may have been in transit to southerly latitudes at the time of their capture. If the sea turtles were not yet migrating, they probably would have begun moving soon. The experience of being captured in a trawl, placed in holding tanks for several days, and equipped with transmitters may have disturbed the sea turtles and stimulated them to begin migrating.

[1]D. Nelson, COE-Waterways Experiment Station, Vicksburg, MS,personal communication, 1991.

Since surface and bottom water temperatures in Brunswick Channel were 25°C and 24.5°C, respectively, on 5 October, temperature was an unlikely factor contributing to initial departure from the area.

Unlike many Kemp's ridleys tracked in Long Island Sound that frequently remain at a single location for extended periods (Morreale and Standora), the two subadult Kemp's ridleys in our study were quite mobile. Successful tracking frequently required continuous monitoring and constant vessel movement to remain within range of the sonic transmitter. Obtaining a stable depth reading from sonic transmitters was sometimes difficult. As a result, depth readings from depth-sensitive tags were recorded infrequently. Nevertheless, data indicated that after initial descent, Kemp's ridleys generally remained at a constant depth at or near bottom during submergence events.

Although data from the satellite tagged Kemp's ridley may be collected until March 1993, preliminary results can be compared with earlier studies of Renaud and Gitschlag (1991). Satellite tracking of a Kemp's ridley released in November 1989 near Mayport, Florida showed movement south to Cape Canaveral by January 1990. However, the Kemp's ridley soon reversed direction and was located in Georgia waters by February, and South Carolina

[2] S. Morreale, Okeanos Research Foundation, 216 East Montauk Highway, Hampton Bays, NY, 11946, personal communication, 1991.

[3] E. Standora, State University College at Buffalo, Department of Biology, 1300 Elmwood Avenue, Buffalo, NY, 14222, personal communication.

waters by March. Two Kemp's ridleys equipped with satellite transmitters were released off Beaufort, North Carolina, in September 1990. One sea turtle remained nearshore in the release vicinity for 5 weeks after which no further transmissions were received. The other Kemp's ridley remained in North Carolina waters during the 5-month study. Movement in relation to water temperature was suggested and the sea turtle utilized warm Gulf Stream waters.

CONCLUSIONS

All three Kemp's ridley sea turtles displayed southerly migration from Georgia to Florida during October. The adult female Kemp's ridley traveled south much faster than the two subadult Kemp's ridleys. The area of the Atlantic Ocean within 37 km of the coast between Stuart and Cape Canaveral, Florida may be an important overwintering area for Kemp's ridleys between mid-November and mid-March. Limited water temperature data indicated a preference for temperatures of 18°C or greater. Although Kemp's ridleys were found within 6 km of St. Mary's Channel on at least seven days, Kemp's ridleys did not appear to take up residence in any of the shipping channels during the study period. One adult male loggerhead sea turtle migrated south into Florida waters.

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Table 1. Size, frequency of transmitters, capture and release date of sea turtles tracked off Georgia-Florida coast during 1991.

Species/ individual	Length (cm) CCL[1]	SCL[2]	Width (cm) CCW[3]	SCW[4]	Capture Date	Release Date	Flipper Tag	Radio Frequency (MHz)	Sonic-Depth Tag (kHz)	Sonic Tag (kHz)	Satellite Tag
Ridley #1	39.4	37.6	42.7	37.0	10/1	10/5	QQR359(R)[5] QQR358(L)[6]	165.339	68	32.7	No
Ridley #2	43.2	41.8	44.5	39.9	10/2	10/6	QQR364(L)	165.611	80	32.7	No
Ridley #3	64.0	60.7	66.6	60.6	10/8	10/13	QQR328(R) QQR327(L)	-	-	-	Yes
Loggerhead #1	94.0	89.0	87.6	68.0	10/3	10/6	QQR301(R) QQR302(L)	165.613	72	-	No
Loggerhead #2	63.5	59.0	57.9	46.0	10/3	10/5	QQR304(R) QQR303(L)	165.558	74	-	No
Loggerhead #3	64.8	61.0	61.0	50.8	10/3	10/5	QQR306(R) QQR305(L)	165.427	70	-	No

[1]Curved carapace length.
[2]Straight carapace length.
[3]Curved carapace width.
[4]Straight carapace width.
[5]Right front flipper.
[6]Left front flipper.

Table 2. T-test for day vs night surface and submergence durations. Asterisks indicate significant difference between day and night durations.

	Surface Duration P	DF	Submergence Duration P	DF
Ridley #1	0.78	237	0.23	168
Ridley #2	0.09	129	<0.01*	91
Both	0.09	368	<0.01*	261

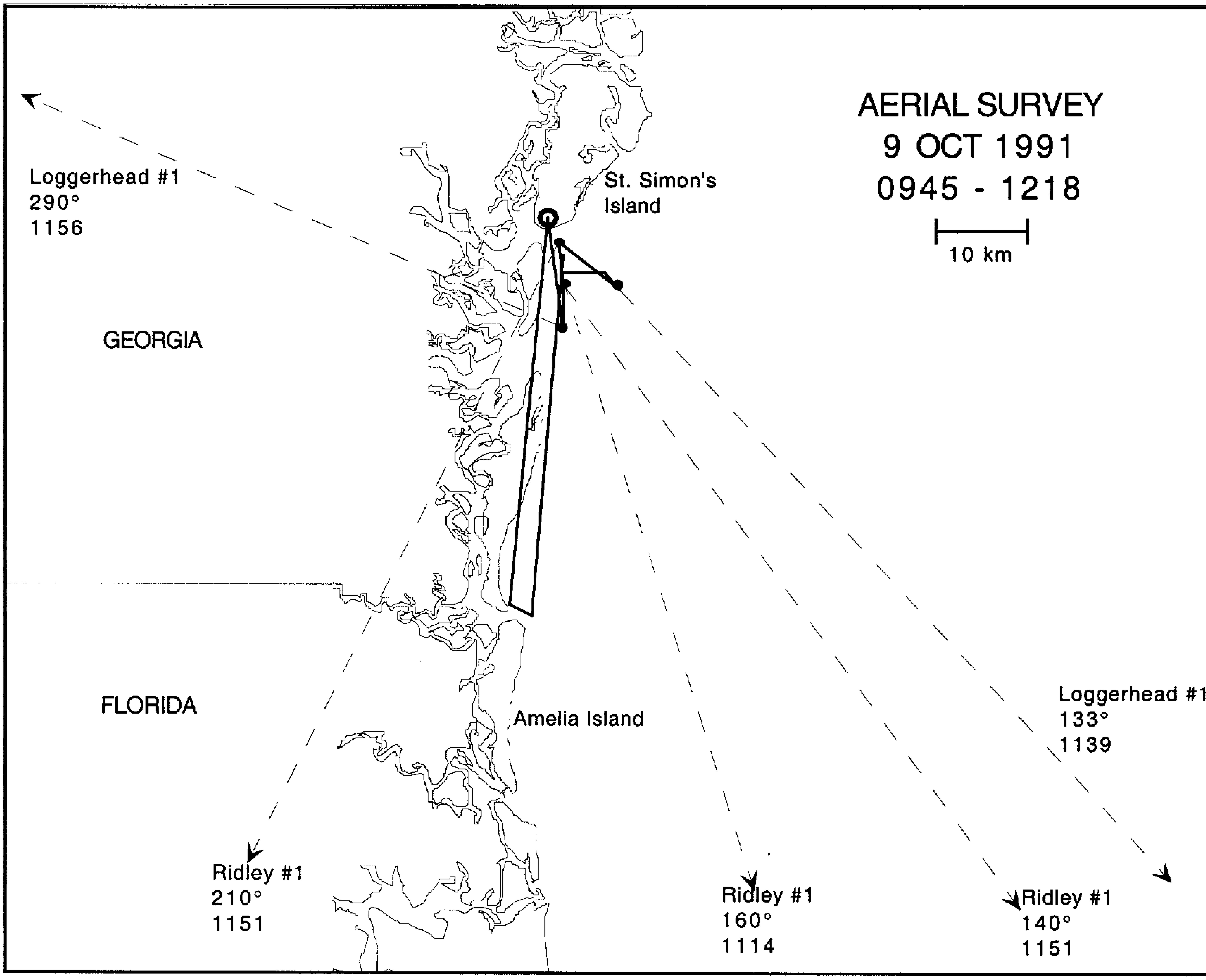

Figure 1. Flight path (solid lines) of aerial survey flown on 9 October 1991. An open circle designates the point of origin and termination of the survey. Dashed lines represent vectors of radio signals recorded aboard the aircraft at locations (closed circles) along the flight path. Turtle identification, bearing and time of signal are shown for each vector.

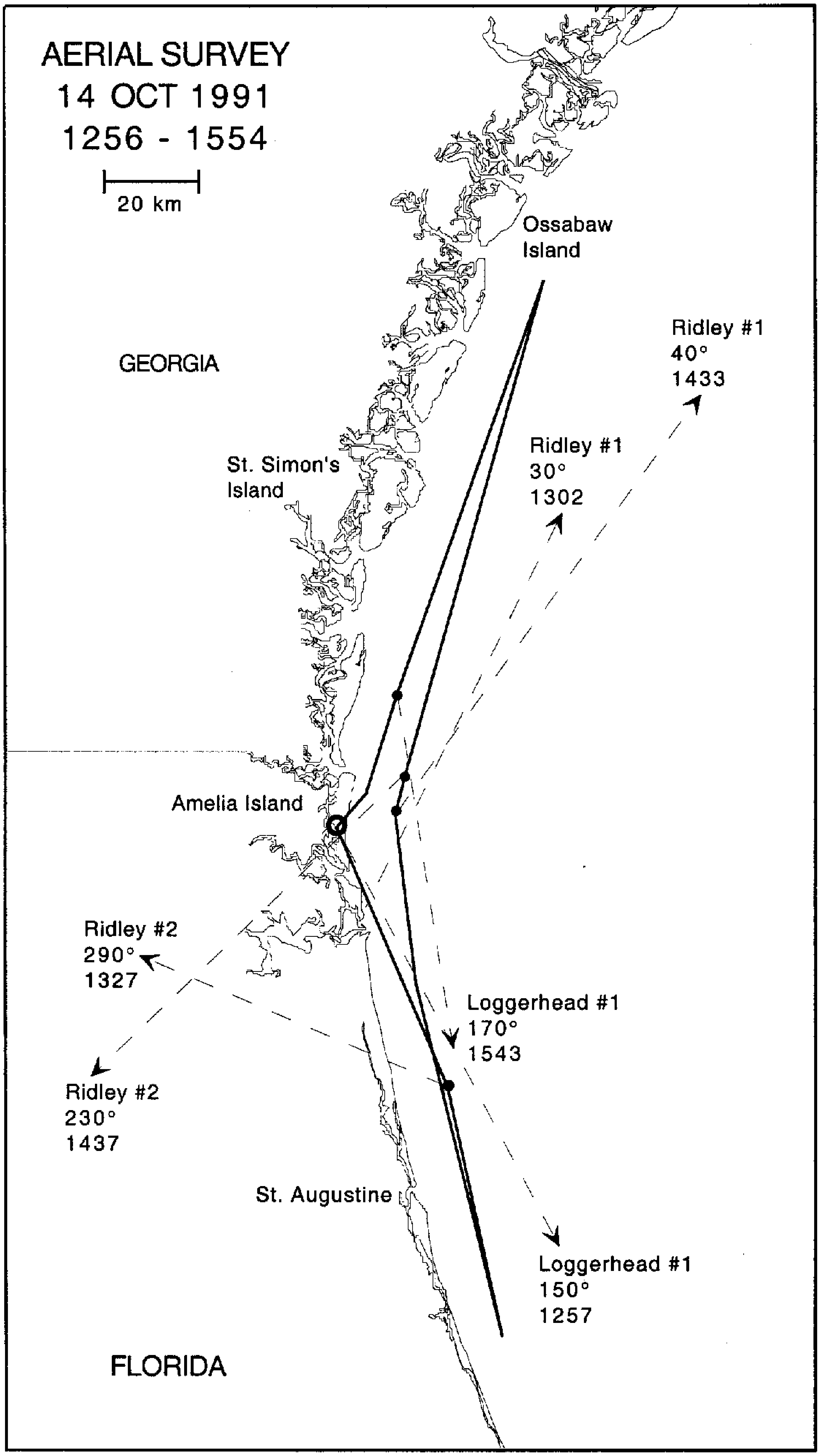

Figure 2. Flight path (solid lines) of aerial survey flown on 14 October 1991. An open circle designates the point of origin and termination of the survey. Dashed lines represent vectors of radio signals recorded aboard the aircraft at locations (closed circles) along the flight path. Turtle identification, bearing and time of signal are shown for each vector.

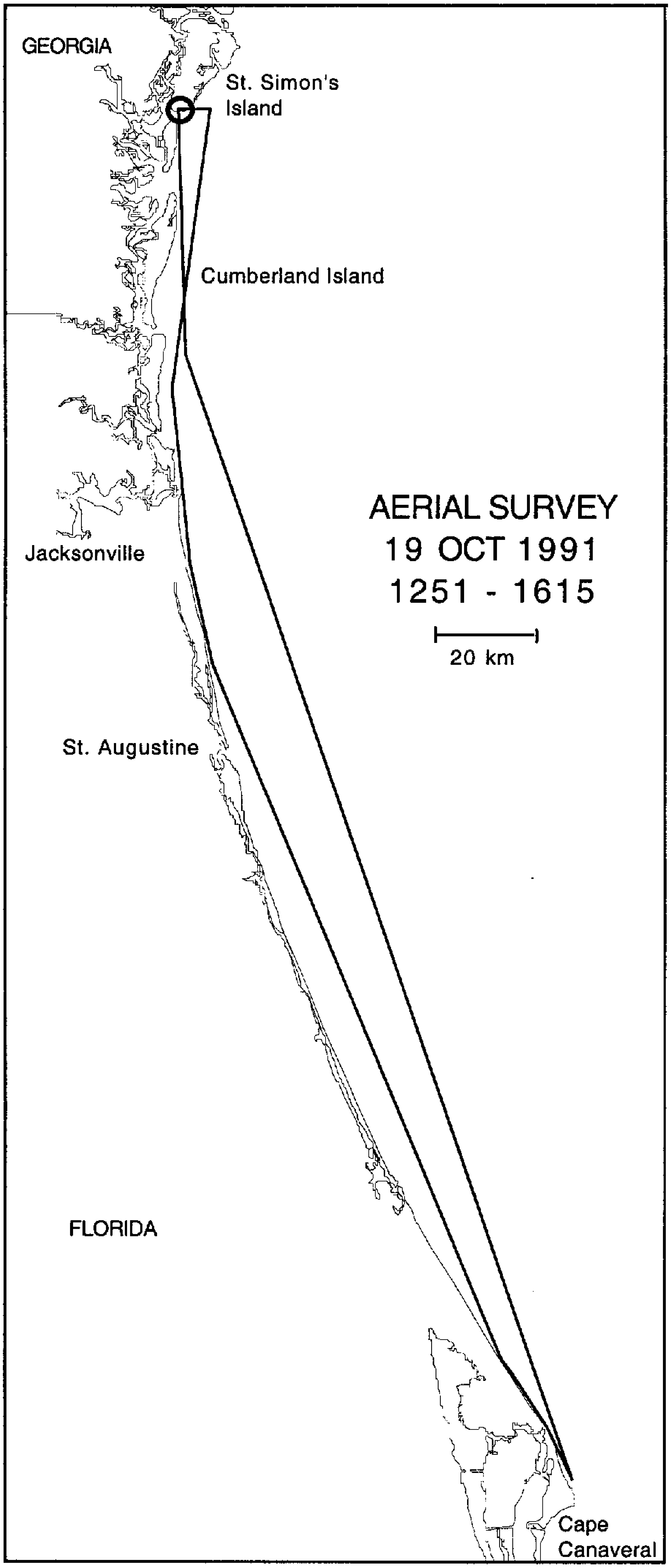

Figure 3. Flight path (solid lines) of aerial survey flown on 19 October 1991. An open circle designates the point of origin and termination of the survey.

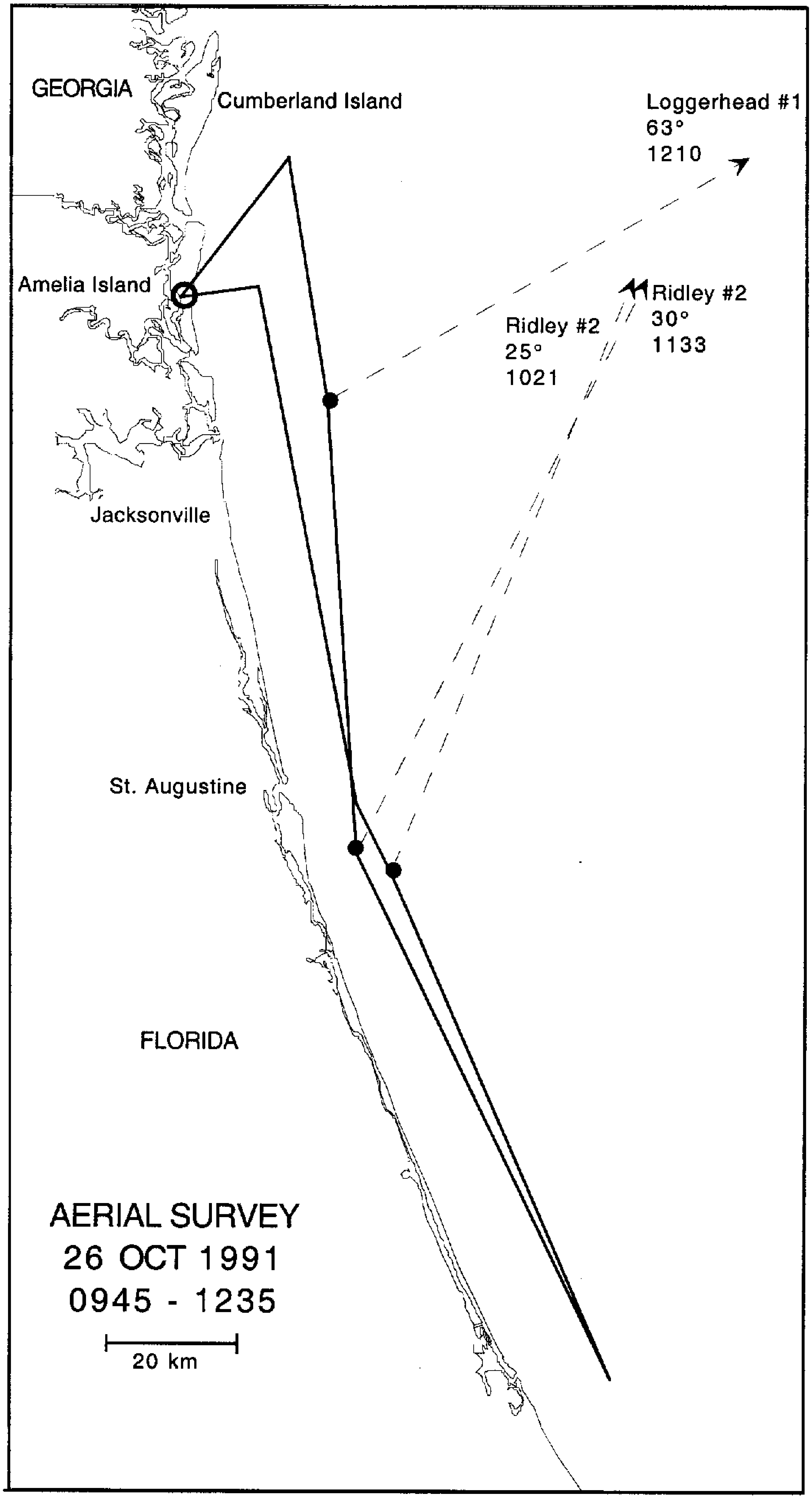

Figure 4. Flight path (solid lines) of aerial survey flown on 26 October 1991. An open circle designates the point of origin and termination of the survey. Dashed lines represent vectors of radio signals recorded aboard the aircraft at locations (closed circles) along the flight path. Turtle identification, bearing and time of signal are shown for each vector.

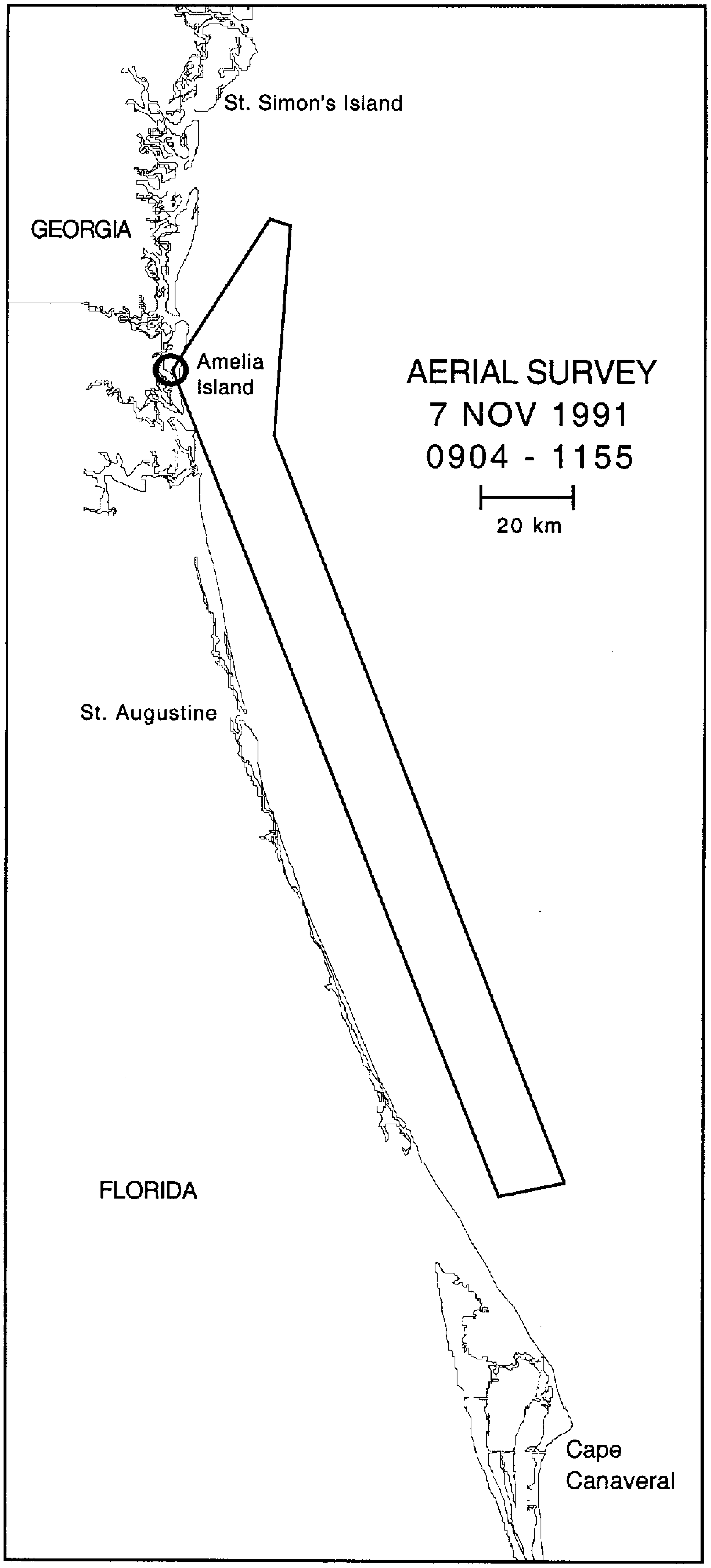

Figure 5. Flight path (solid lines) of aerial survey flown on 7 November 1991. An open circle designates the point of origin and termination of the survey.

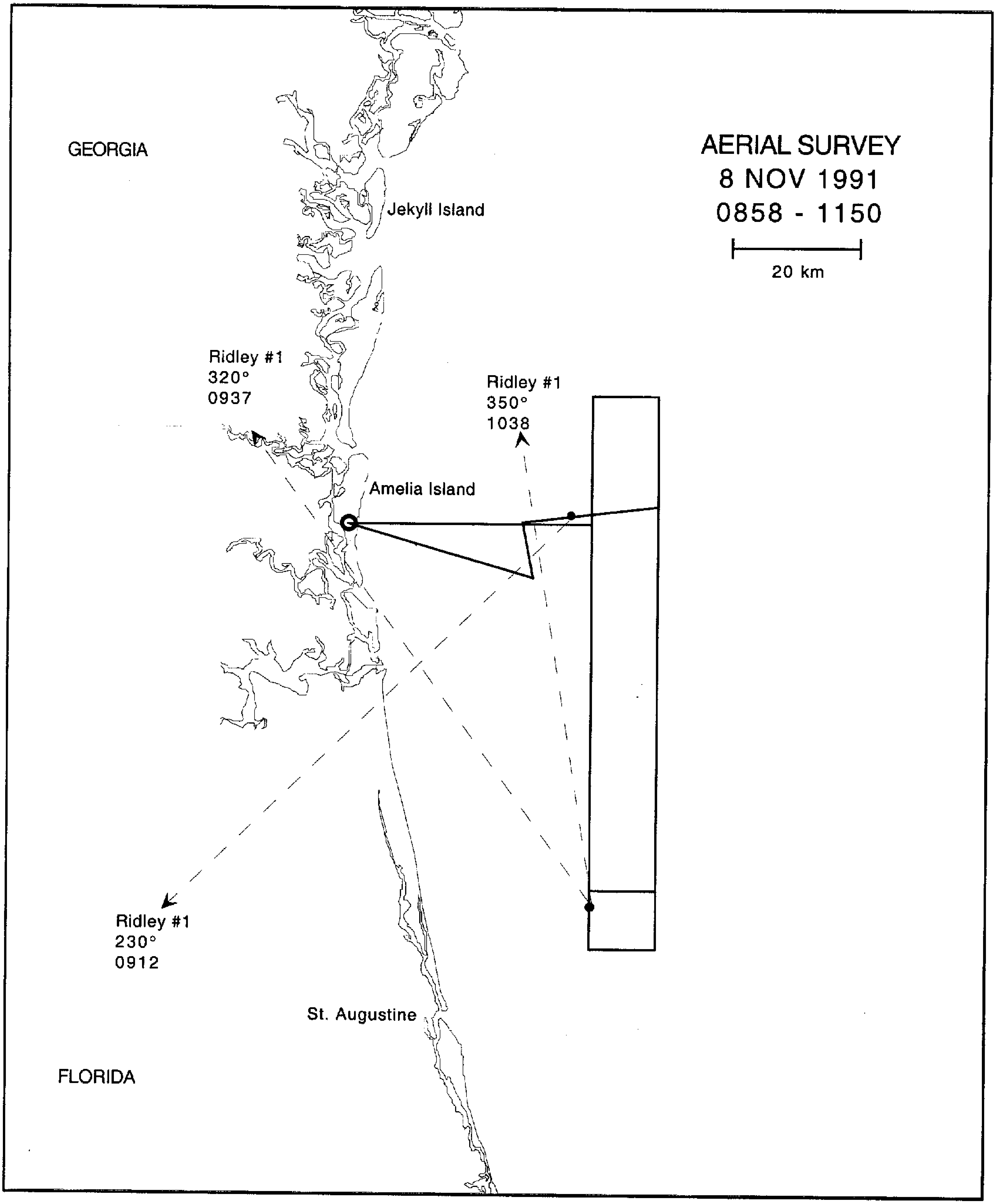

Figure 6. Flight path (solid lines) of aerial survey flown on 8 November 1991. An open circle designates the point of origin and termination of the survey. Dashed lines represent vectors of radio signals recorded aboard the aircraft at locations (closed circles) along the flight path. Turtle identification, bearing and time of signal are shown for each vector.

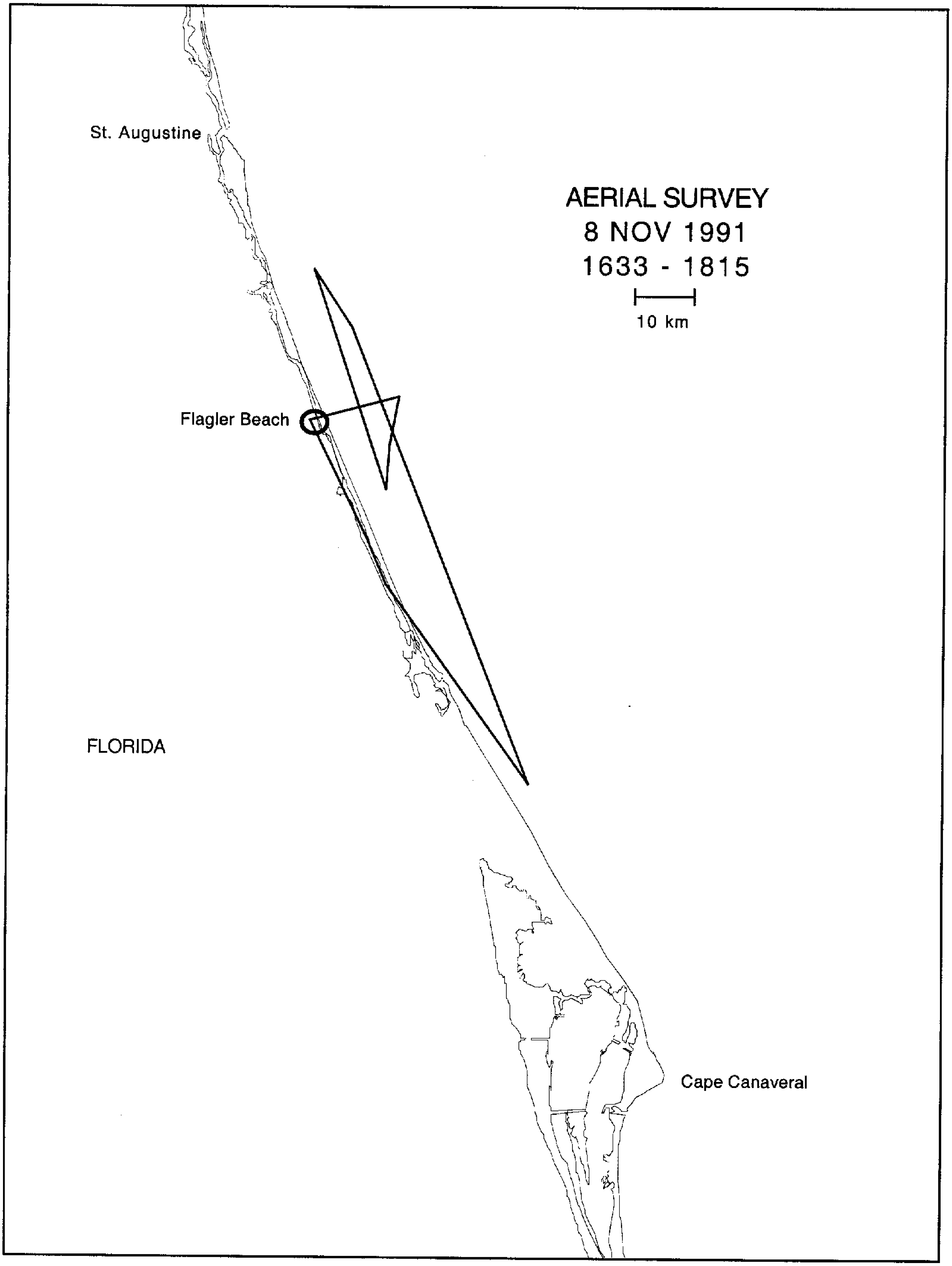

Figure 7. Flight path (solid lines) of aerial survey flown on 8 November 1991. An open circle designates the point of origin and termination of the survey.

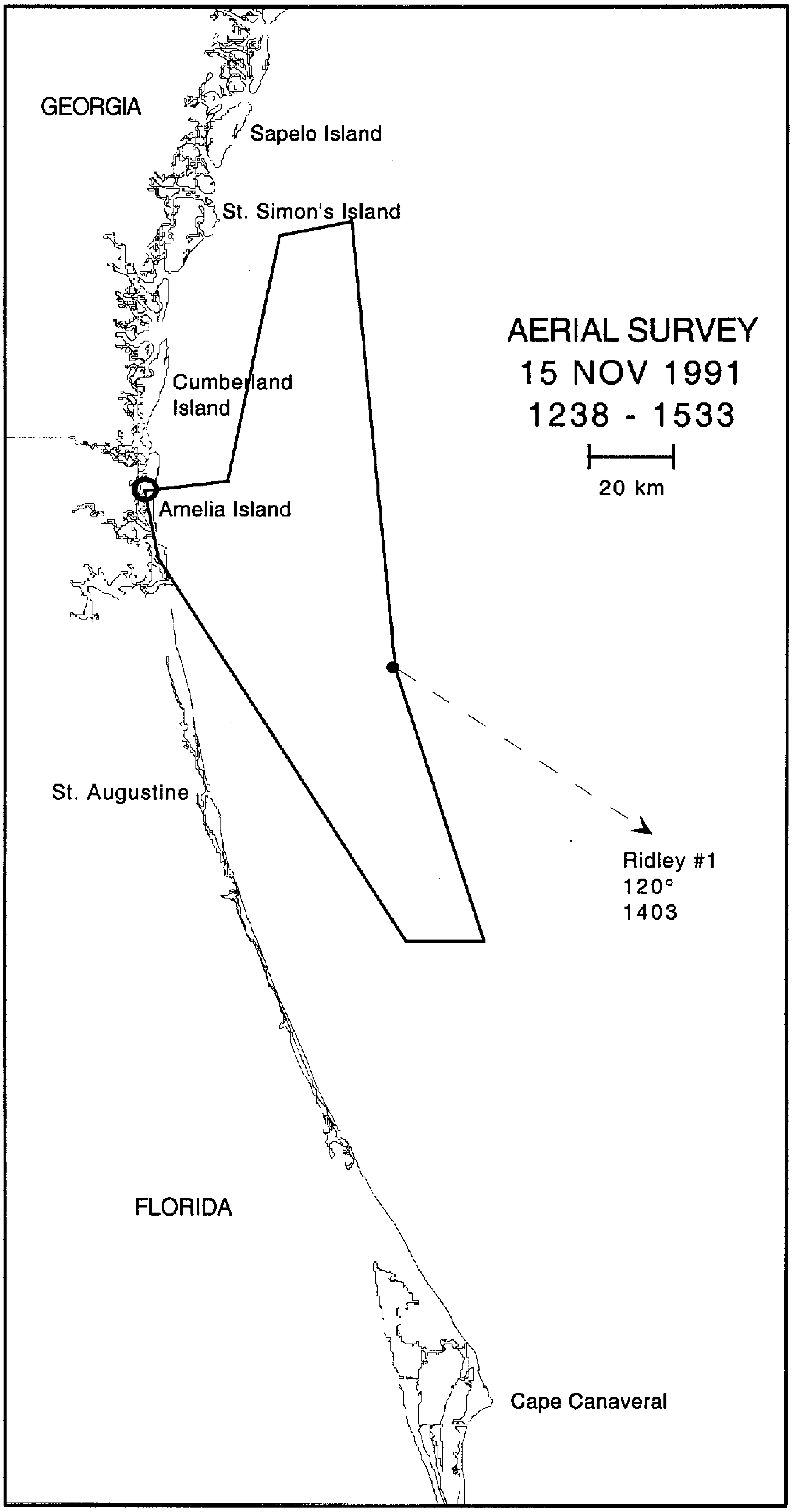

Figure 8. Flight path (solid lines) of aerial survey flown on 15 November 1991. Dashed lines represent vectors of radio signals recorded aboard the aircraft at locations (closed circles) along the flight path. Turtle identification, bearing and time of signal are shown for each vector.

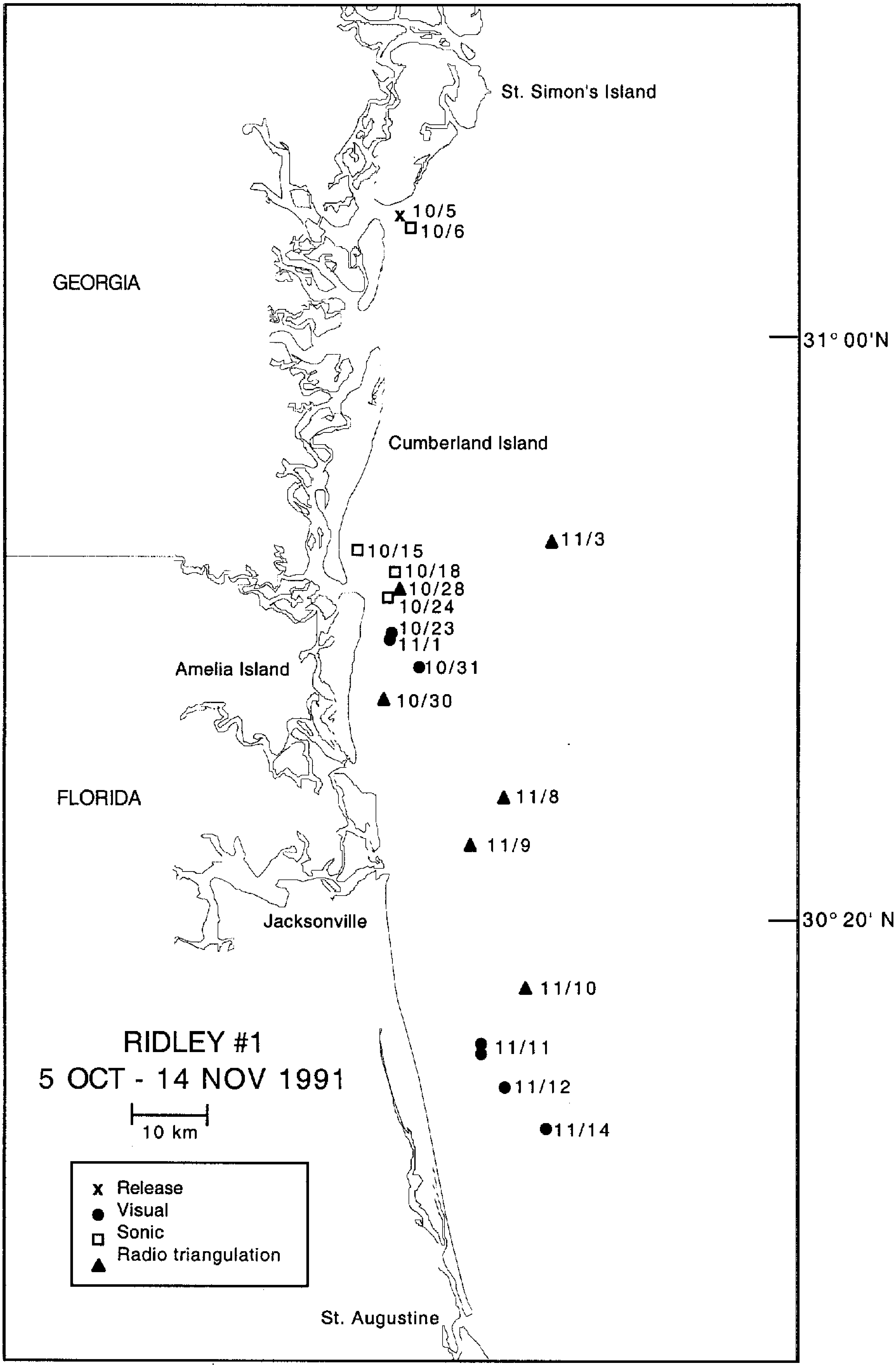

Figure 9. Locations of Kemp's Ridley #1 from 5 October - 14 November 1991.

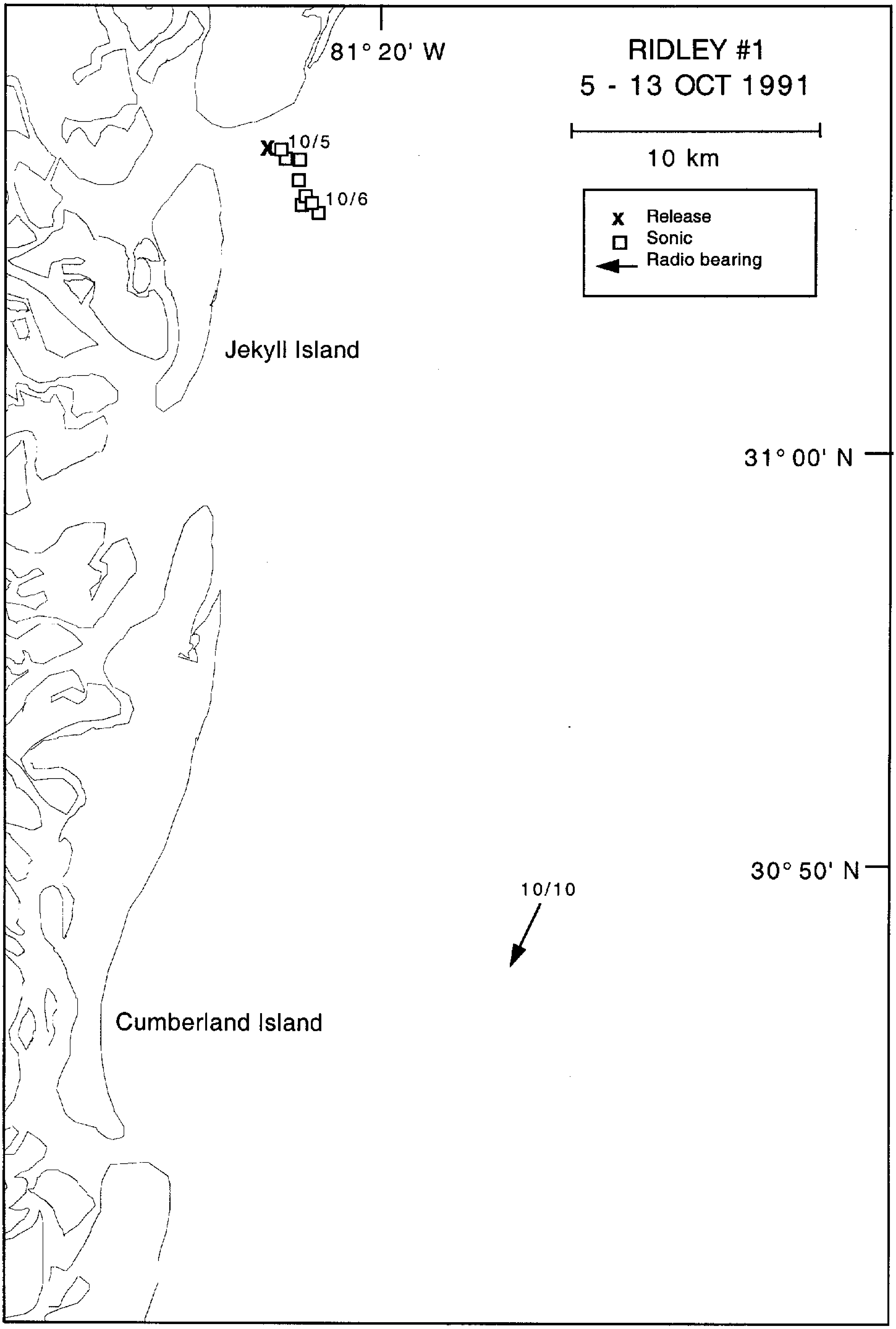

Figure 10. Locations of Kemp's Ridley #1 from 5 - 13 October 1991.

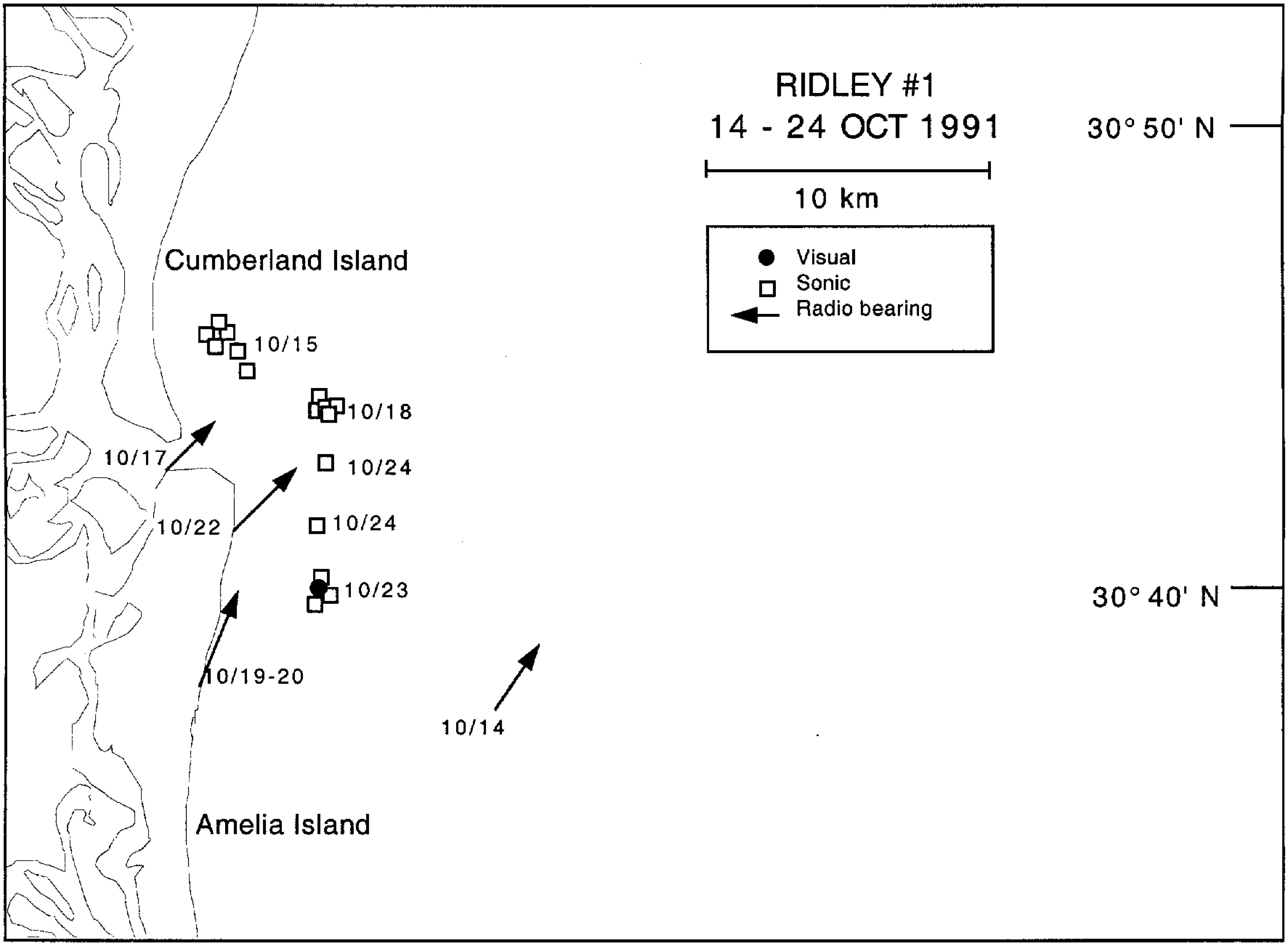

Figure 11. Locations of Kemp's Ridley #1 from 14 - 24 October 1991.

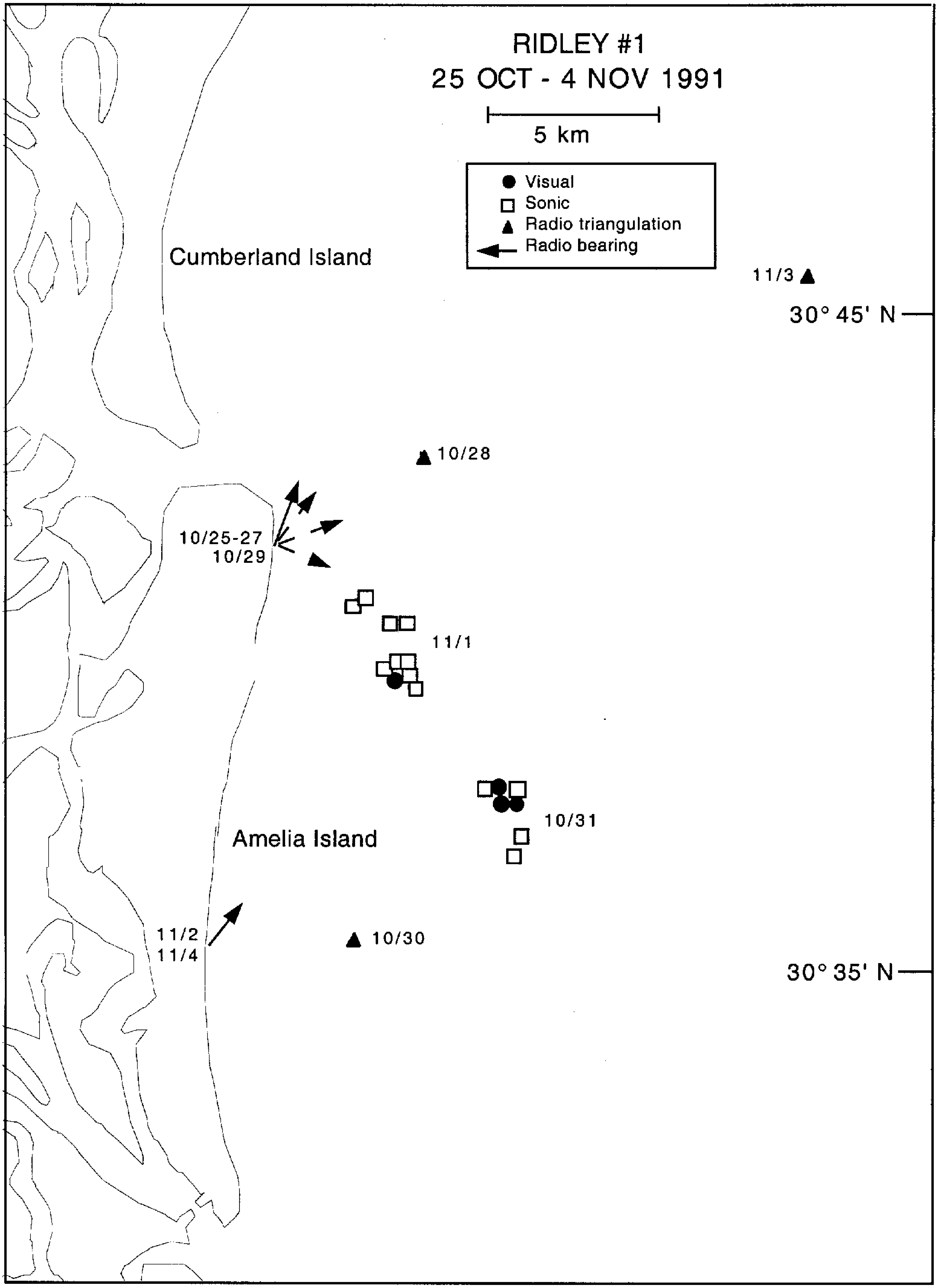

Figure 12. Locations of Kemp's Ridley #1 from 25 October - 4 November 1991.

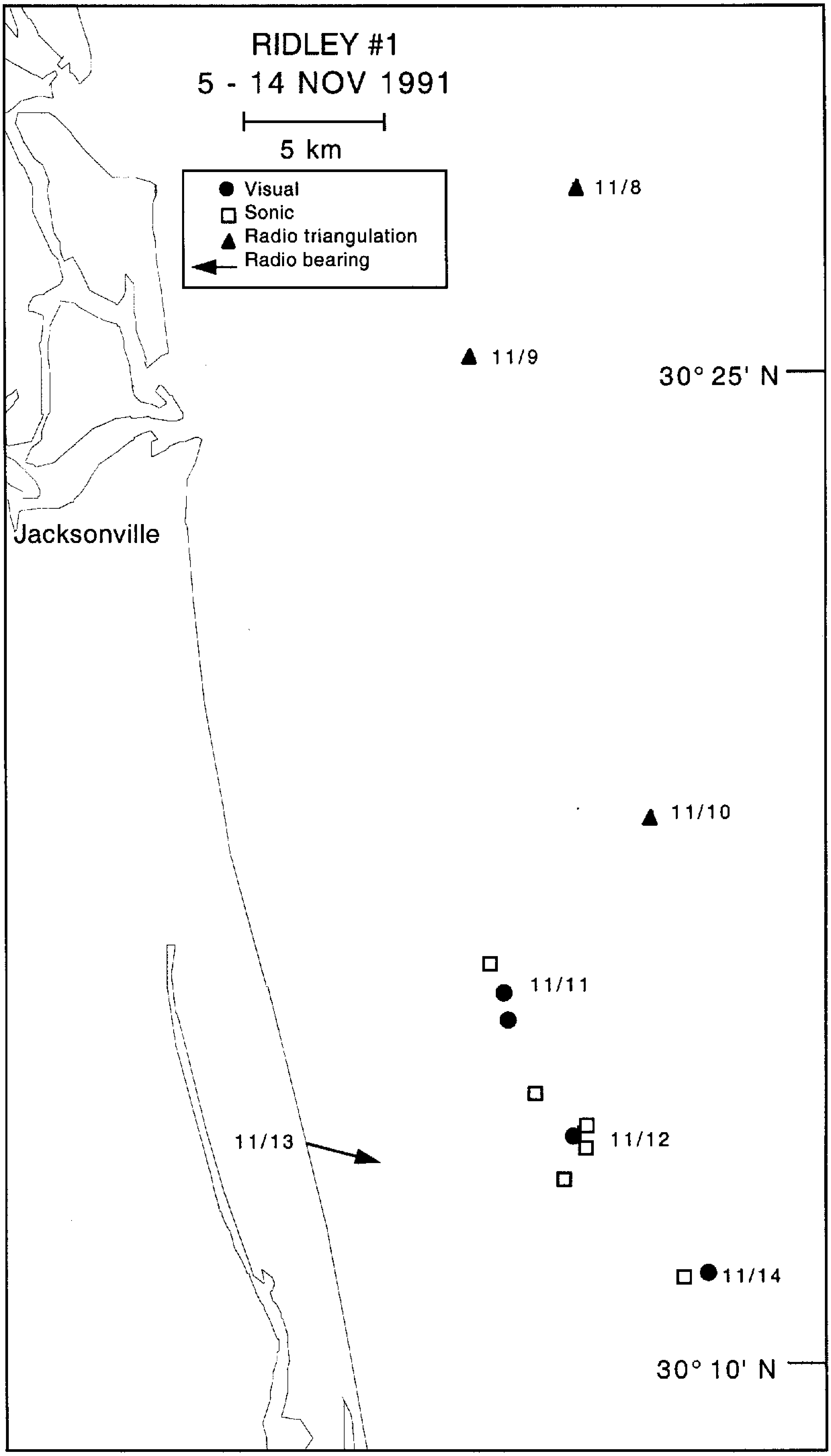

Figure 13. Locations of Kemp's Ridley #1 from 5 - 14 November 1991.

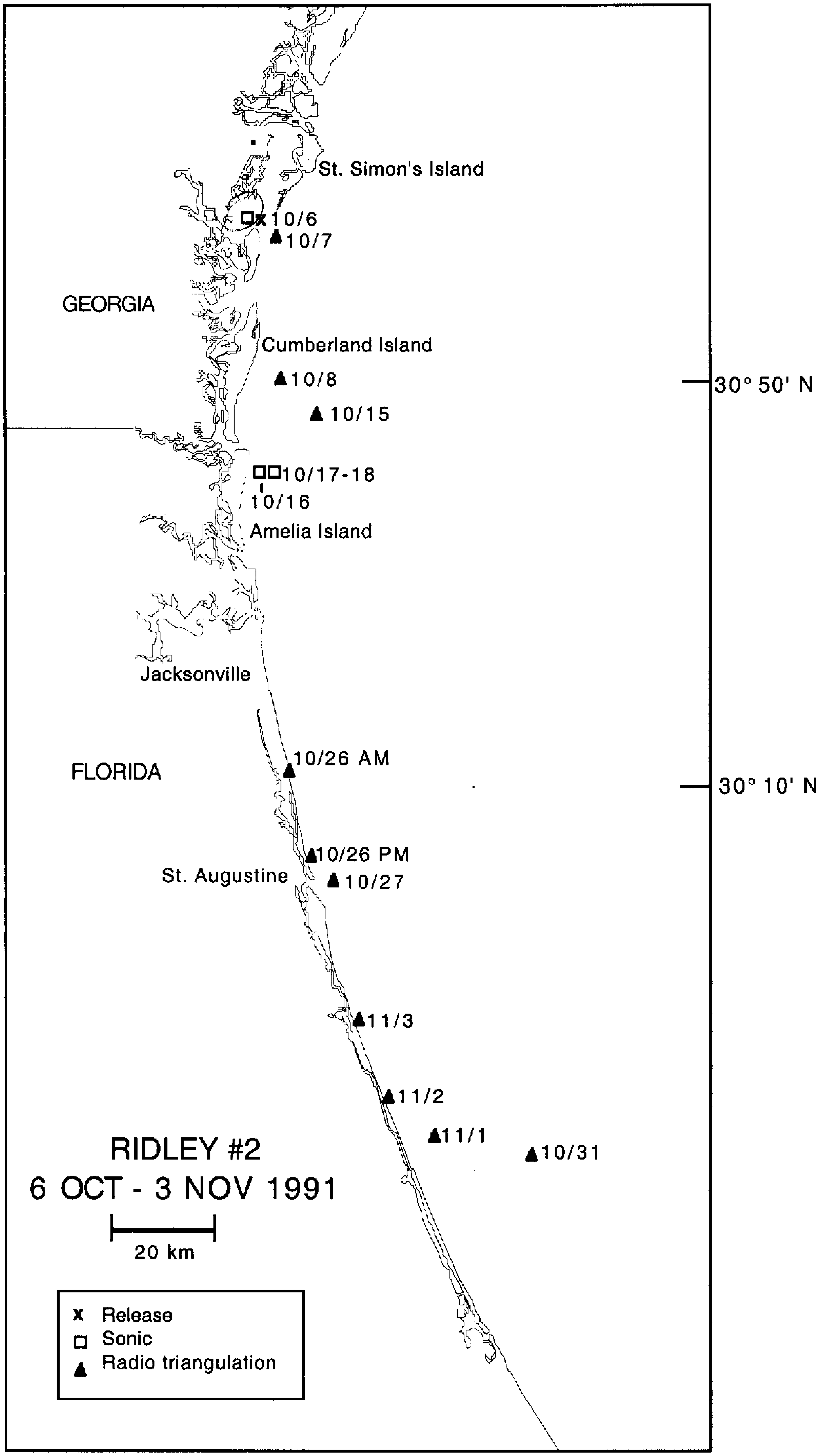

Figure 14. Locations of Kemp's Ridley #2 from 6 October - 3 November 1991.

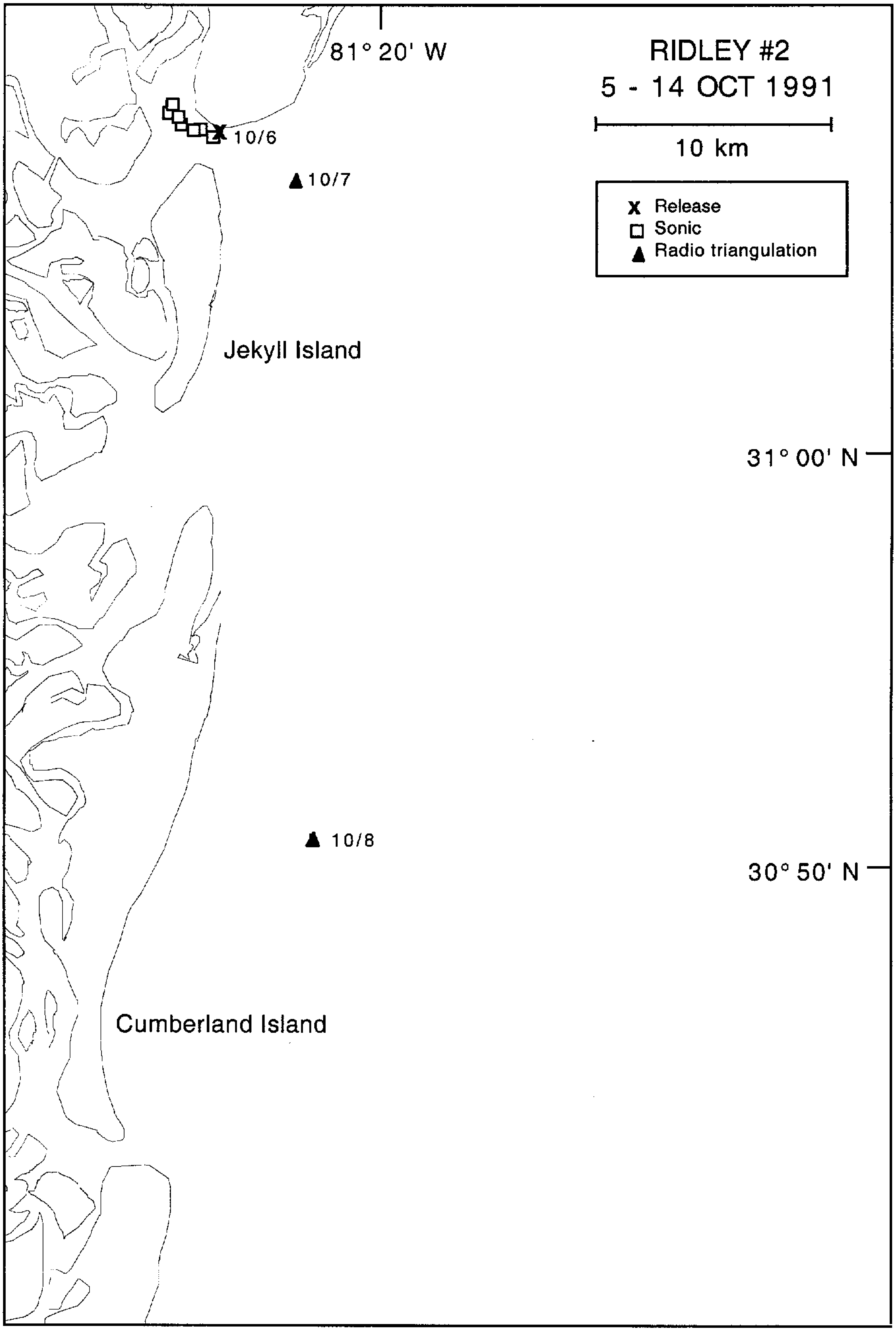

Figure 15. Locations of Kemp's ridley #2 from 5 - 14 October 1991.

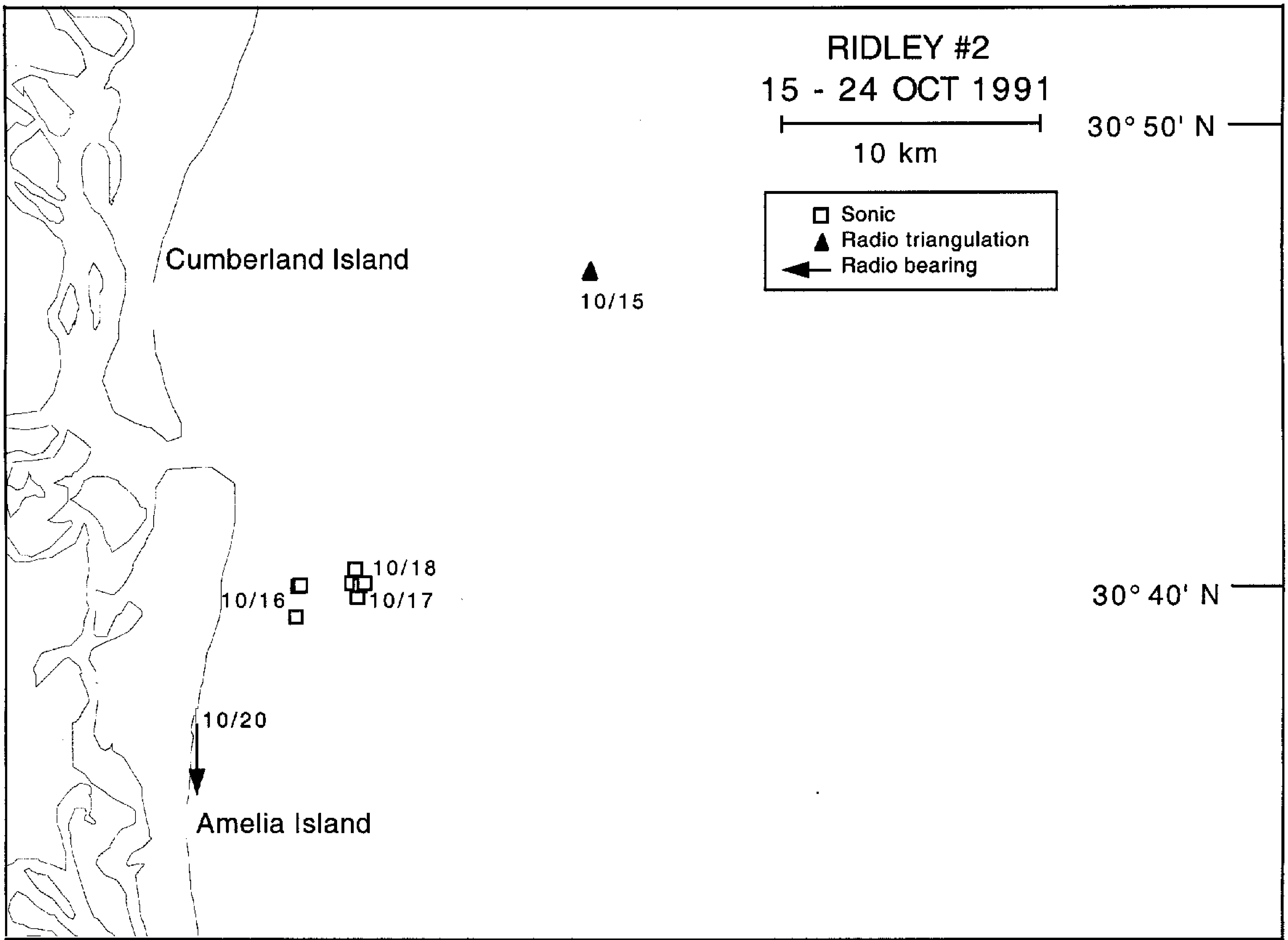

Figure 16. Locations of Kemp's ridley #2 from 15 - 24 October 1991.

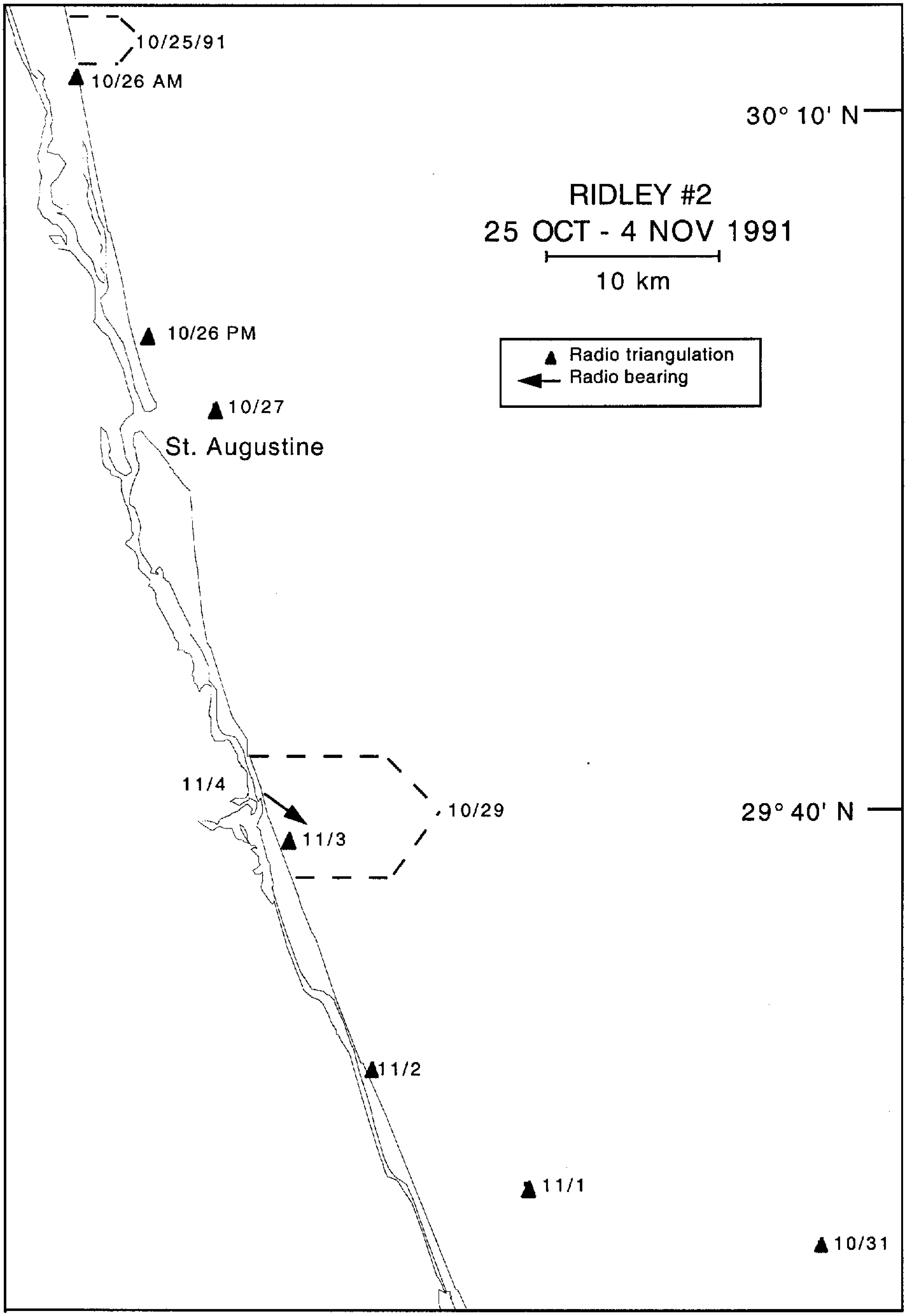

Figure 17. Locations of Kemp's Ridley #2 from 25 October - 04 November 1991. On 25 and 29 October, the sea turtle was located between the bracketed latitudes. On 26 October, morning (AM) and afternoon (PM) locations are shown.

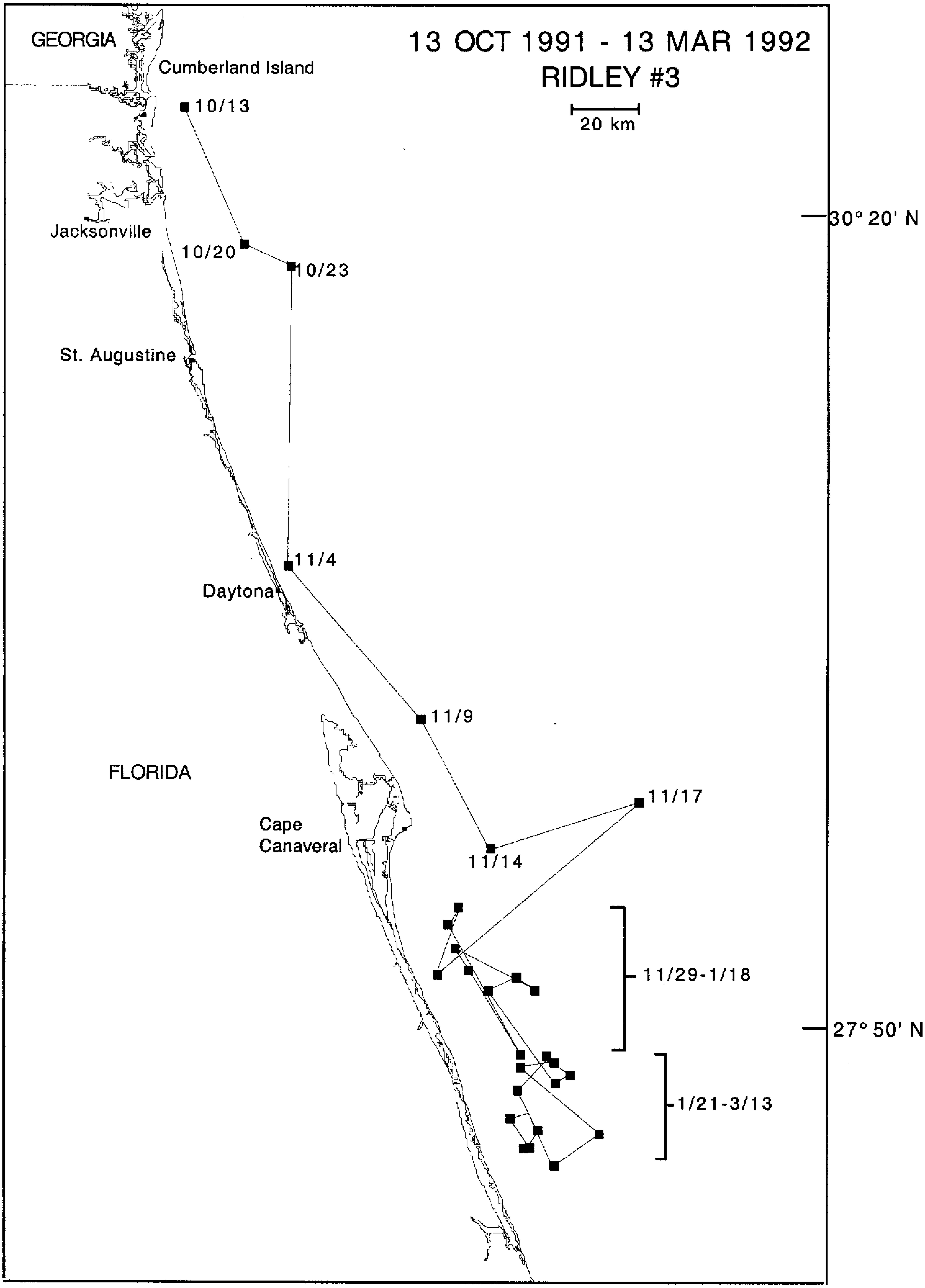

Figure 18. Movement of satellite-tracked Kemp's Ridley #3 from 13 October 1991 - 13 March 1992.

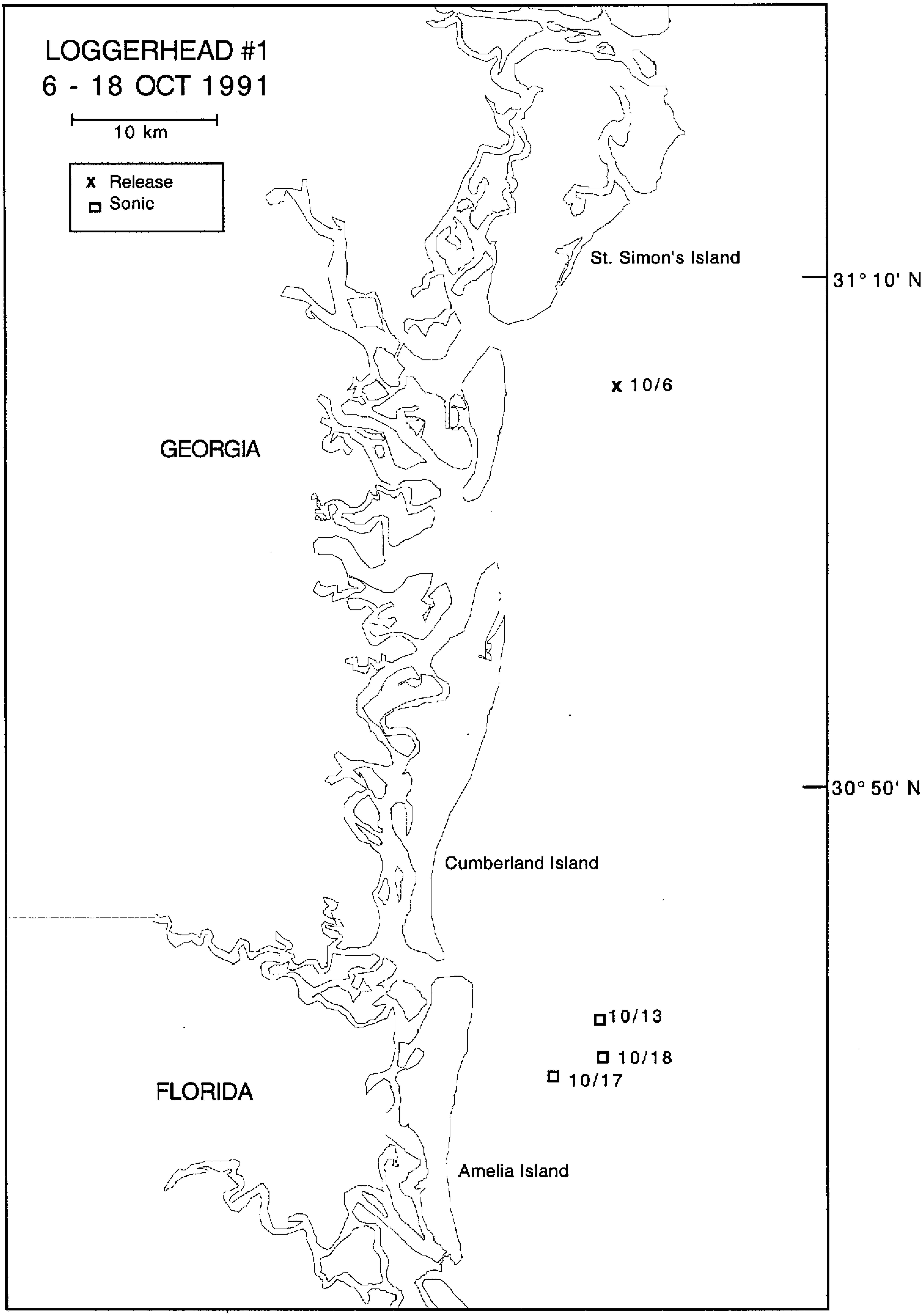

Figure 19. Locations of Loggerhead #1 from 6 - 18 October 1991.

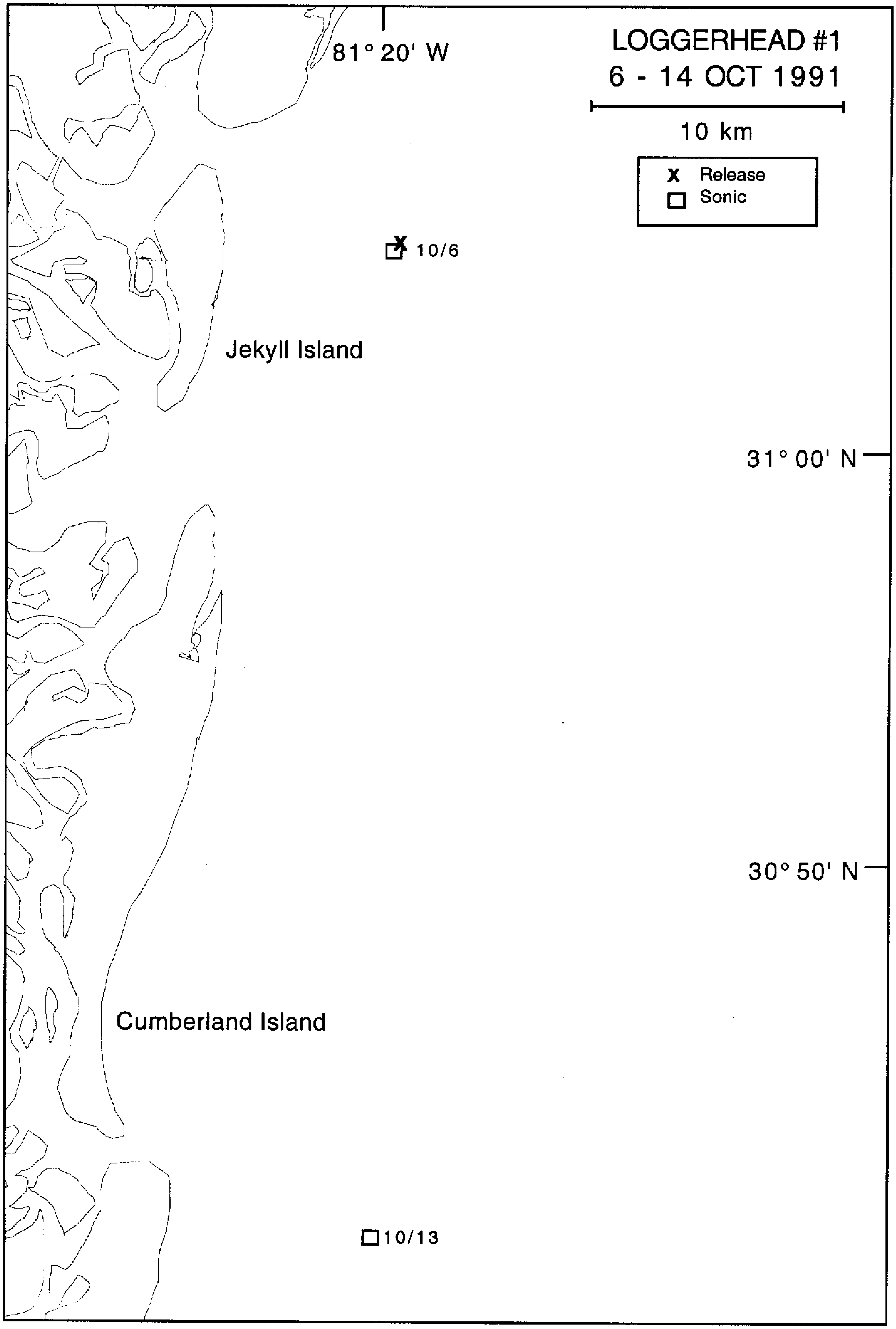

Figure 20. Locations of Loggerhead #1 from 6 - 14 October 1991.

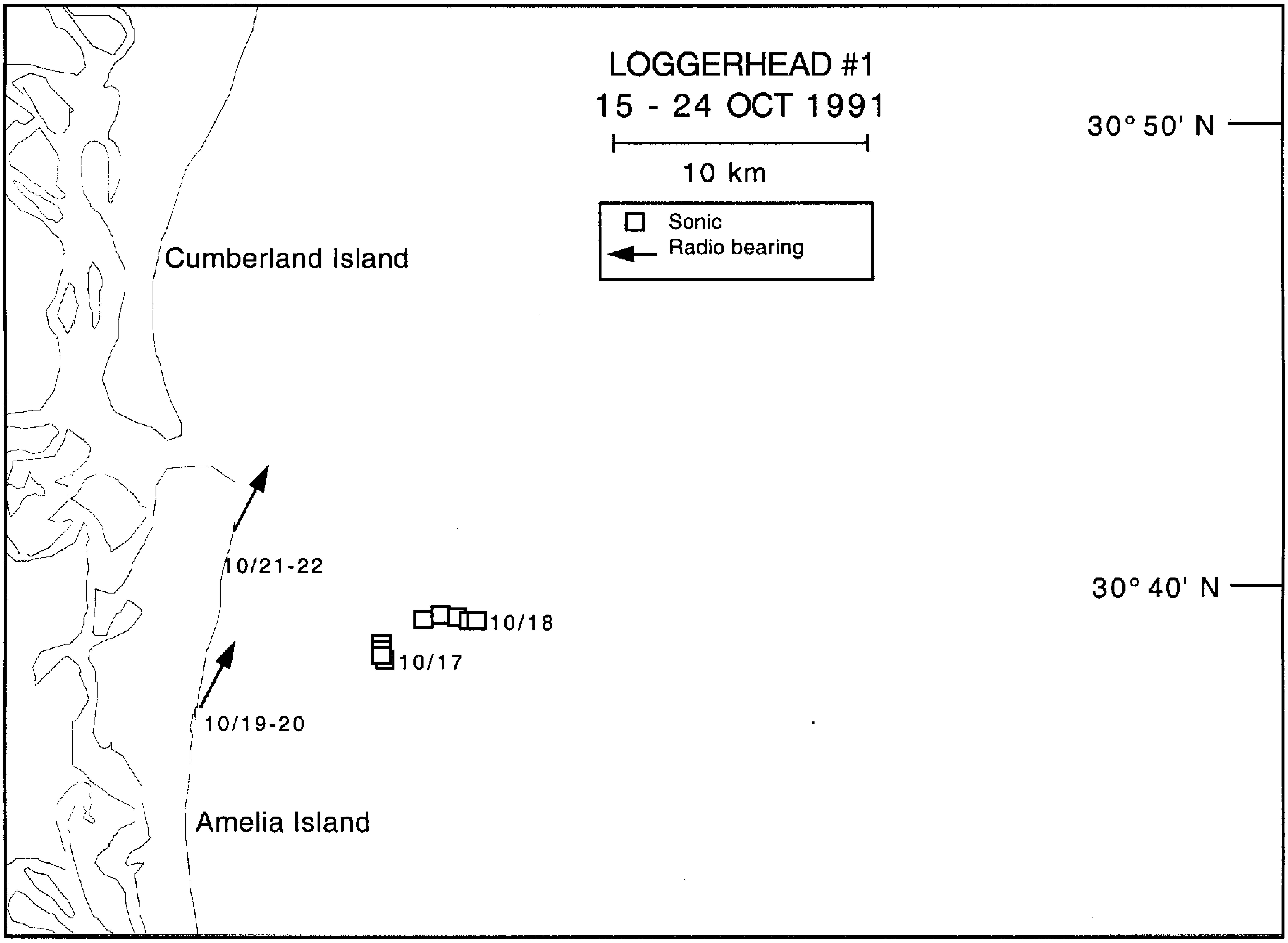

Figure 21. Locations of Loggerhead #1 from 15 - 24 October 1991.

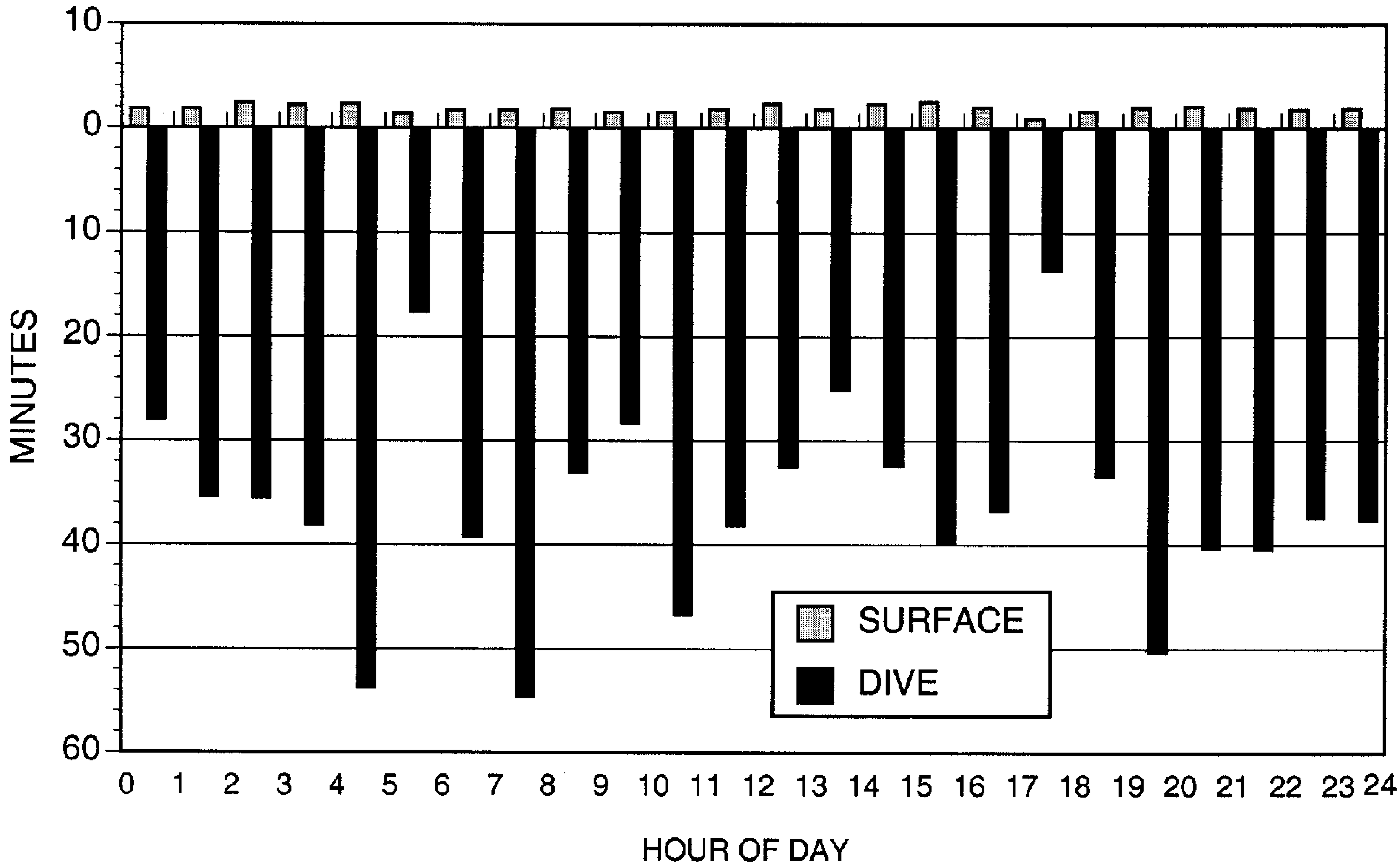

Figure 22. Mean surfaced and submerged durations by hour of day for Kemp's Ridley #1.

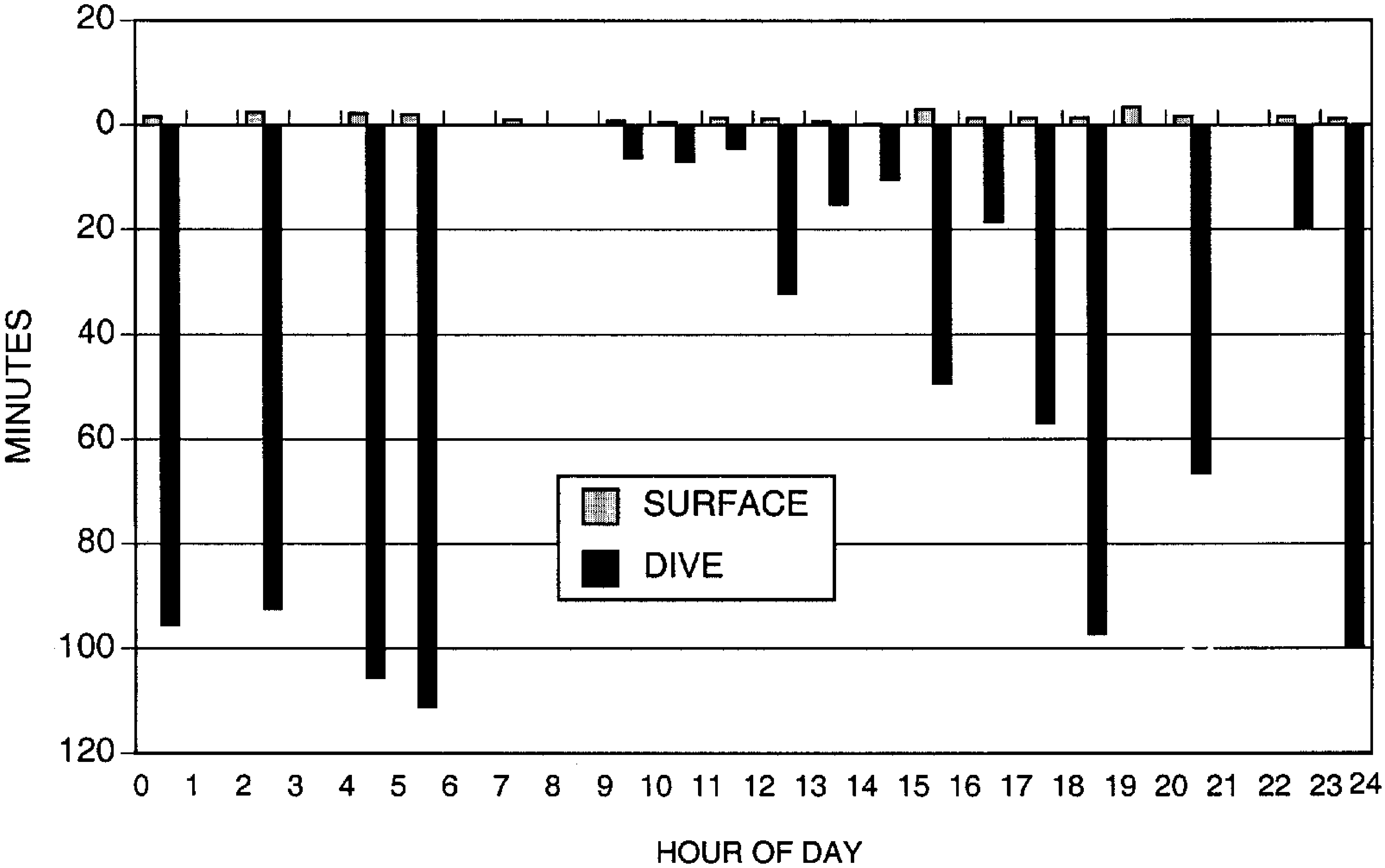

Figure 23. Mean surfaced and submerged durations by hour of day for Kemp's ridley #2.

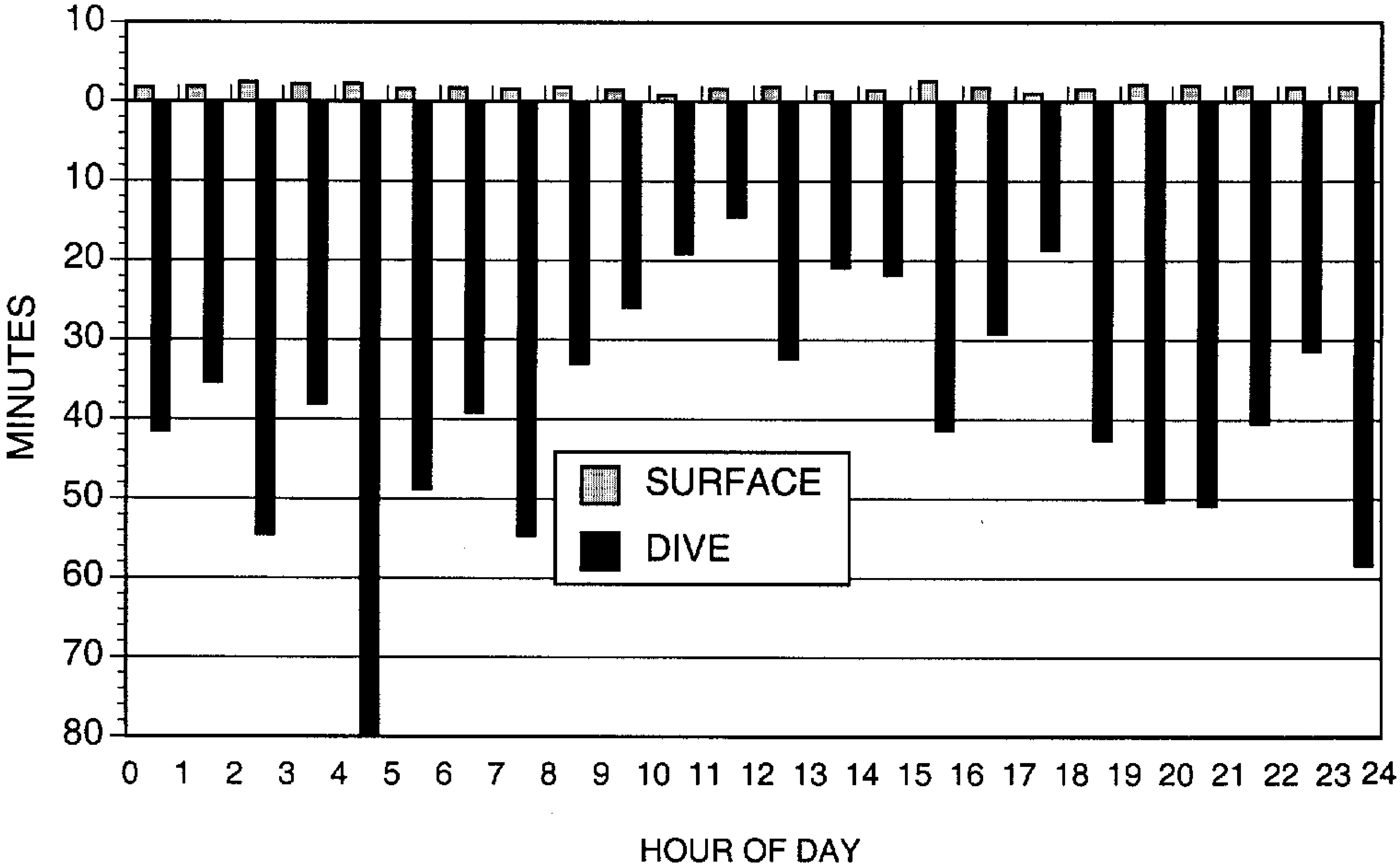

Figure 24. Mean surfaced and submerged durations by hour of day for both Kemp's Ridleys #1 and #2 combined.

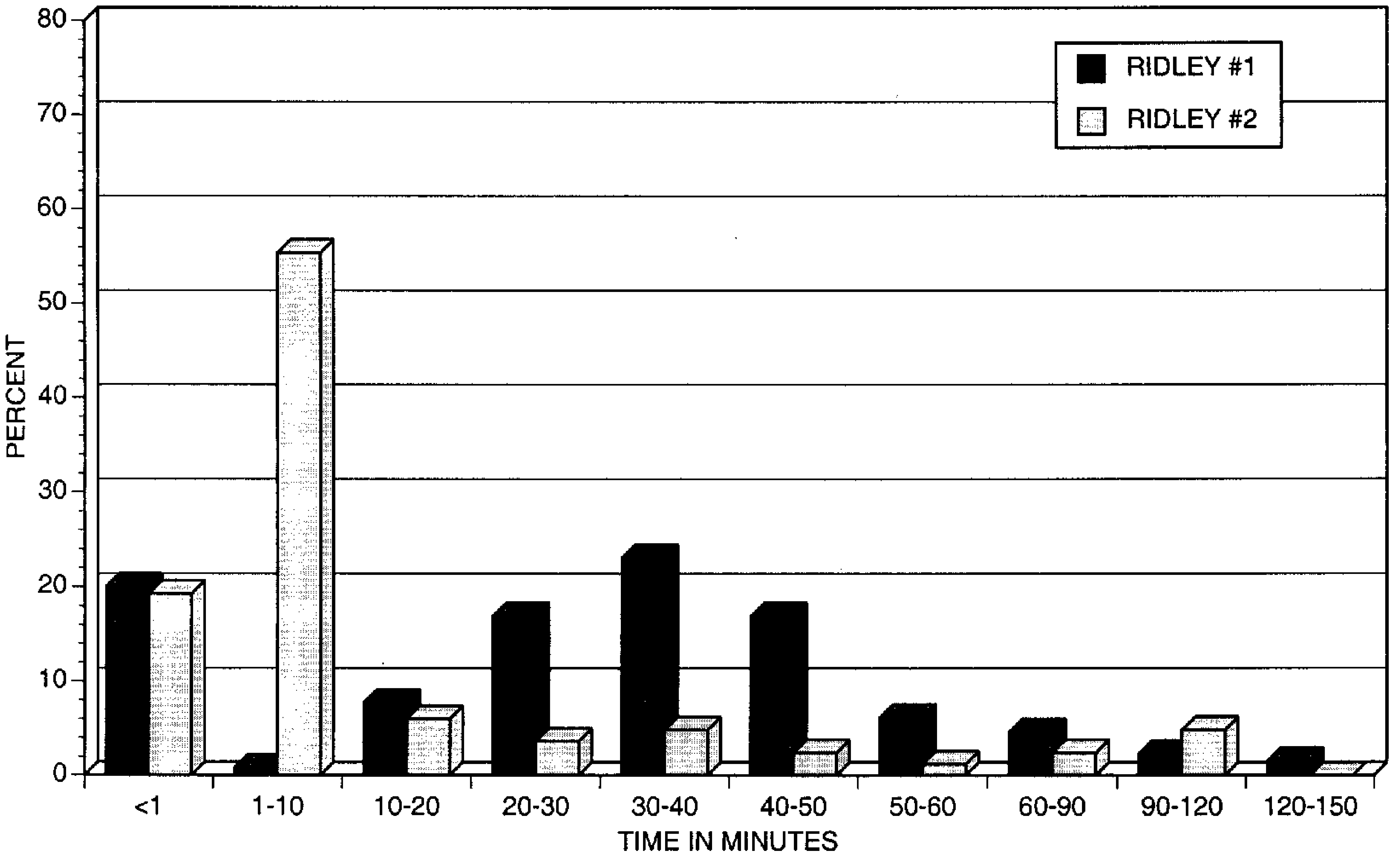

Figure 25. Percentage of day submergences by dive duration for Kemp's Ridleys #1 and #2.

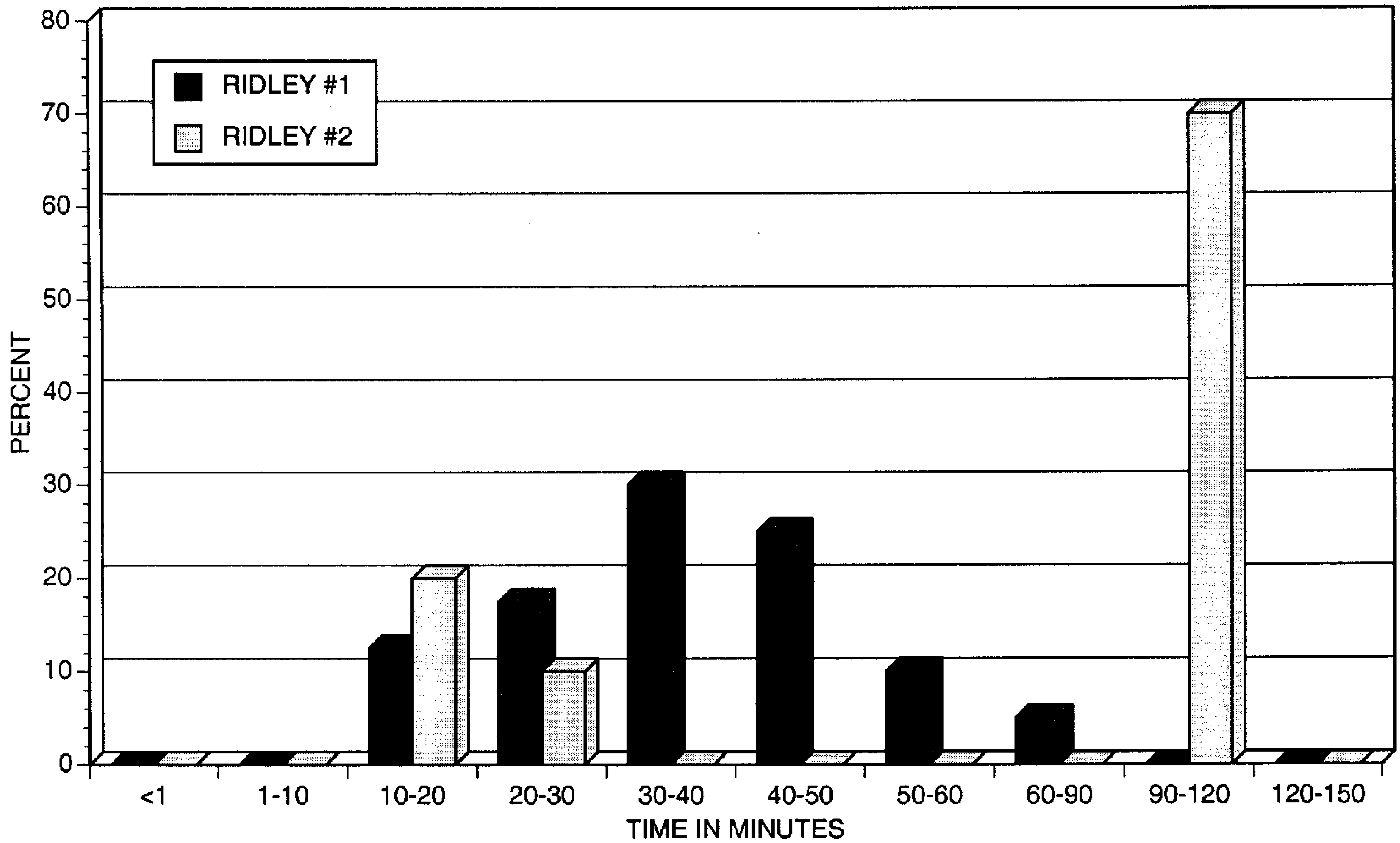

Figure 26. Percentage of night submergences by dive duration for Kemp's Ridleys #1 and #2.

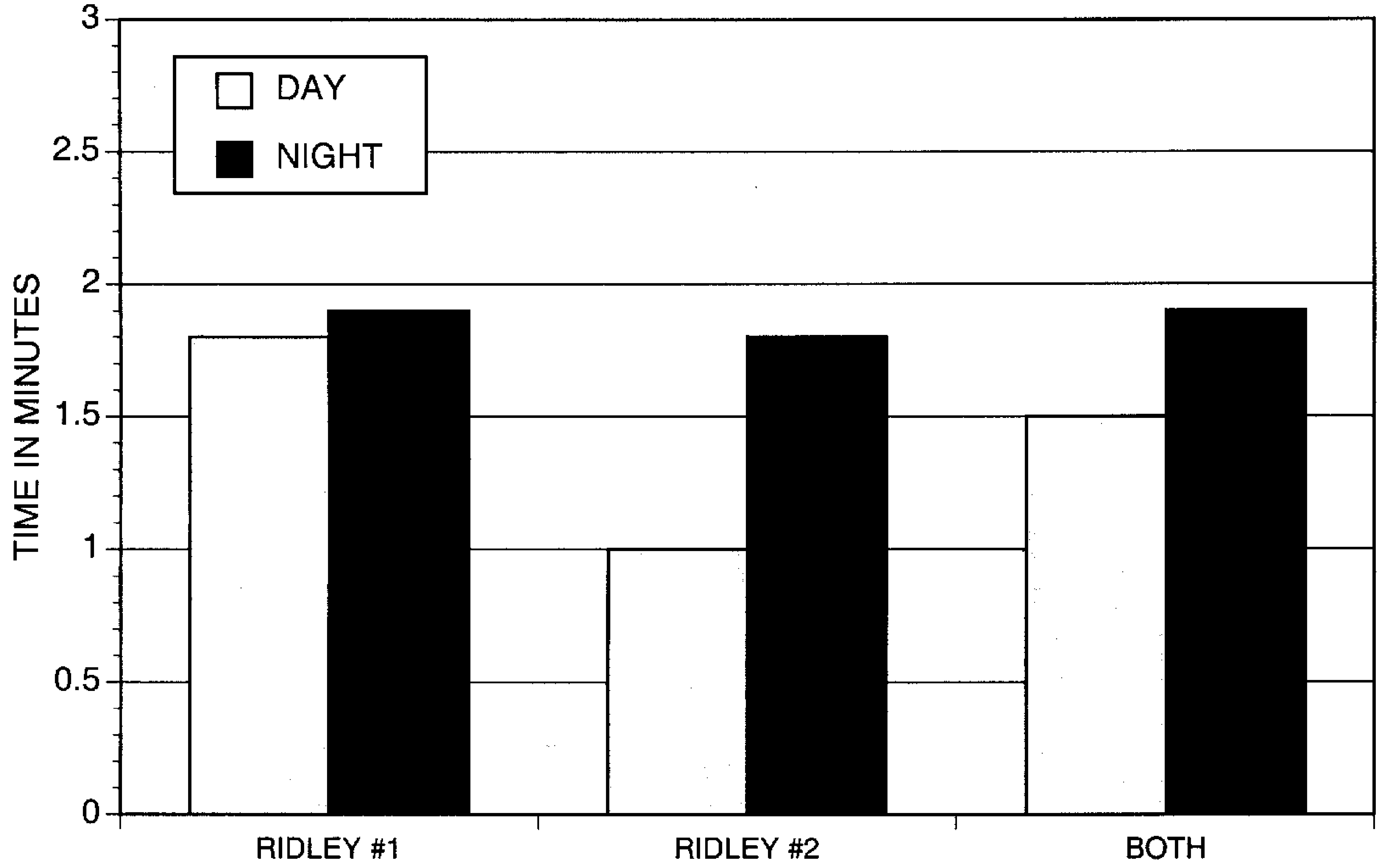

Figure 27. Mean duration of surface intervals (day vs night) for Kemp's Ridleys #1, #2 and both sea turtles combined.

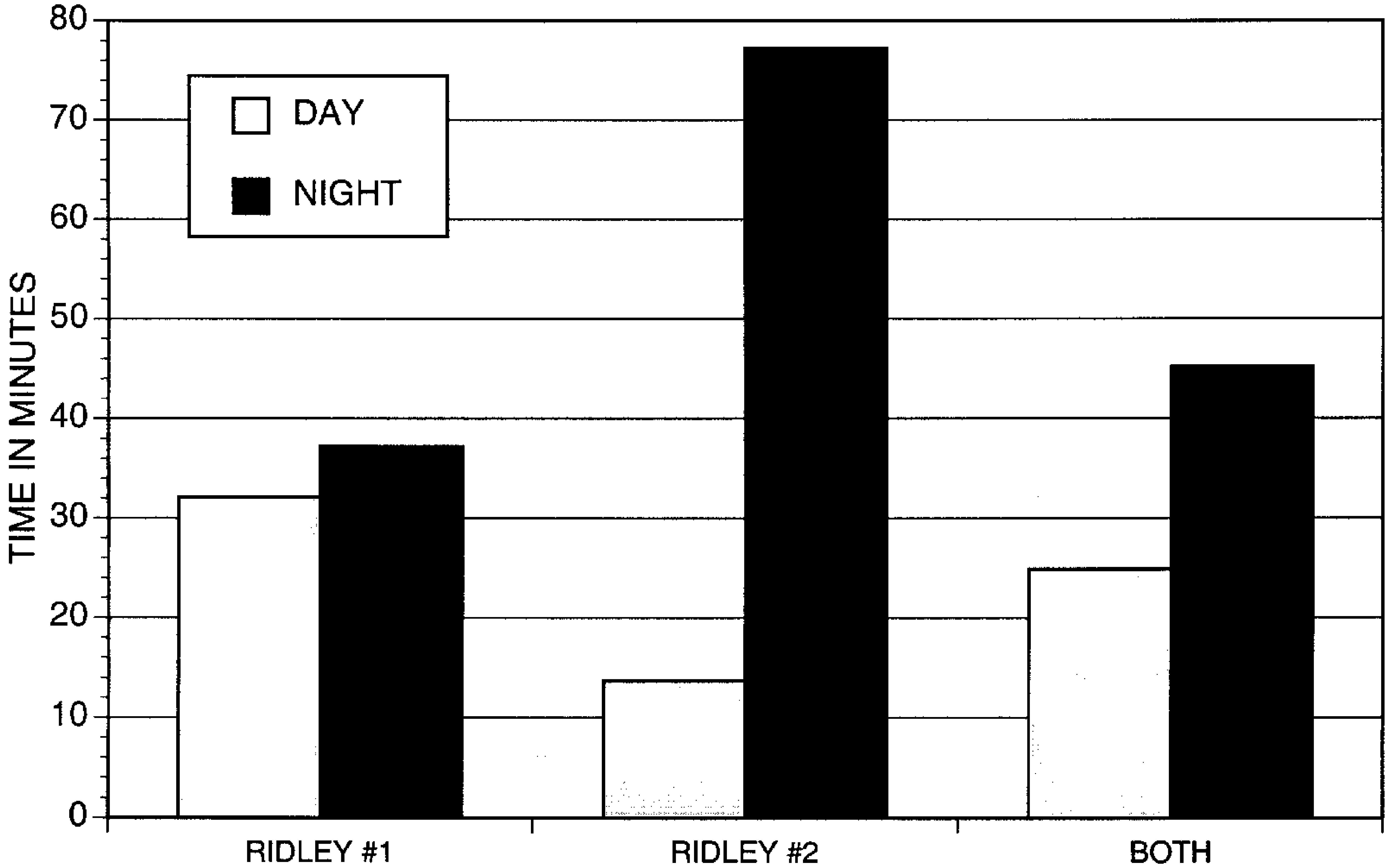

Figure 28. Mean submergence duration (day vs night) for Kemp's Ridleys #1, #2 and both turtles combined.

Appendix I. Water temperatures and salinities collected throughout the study period.

MONTH	DAY	YEAR	LATITUDE	LONGITUDE	SURFACE TEMP (°C)	BOTTOM TEMP (°C)	SURFACE SALINITY (PPT)	BOTTOM SALINITY (PPT)	DEPTH (M)
10	22	91	30°42'40"	81°27'34"	23.5	-	24.5	-	-
10	23	91	30°39'55"	81°23'29"	24.0	-	26.0	-	11.3
10	23	91	30°39'59"	81°23'35"	24.0	-	23.0	-	10.7
10	23	91	30°40'00"	81°23'35"	24.5	-	-	-	-
10	27	91	29°54'58"	81°17'28"	25.0	-	23.0	-	-
10	27	91	29°57'04"	81°18'18"	24.5	-	26.0	-	-
10	28	91	30°42'30"	81°27'04"	23.5	23.5	25.0	25.5	17.7
10	28	91	30°42'31"	81°23'13''	23.8	23.0	25.0	26.0	-
10	28	91	30°42'41"	81°27'48"	24.5	24.0	24.0	23.0	-
10	28	91	30°41'00"	81°25'50"	-	-	-	-	-
10	29	91	29°57'04"	81°18'18"	23.0	-	29.0	-	-
10	29	91	29°54'58"	81°17'28"	24.0	-	25.5	-	-
10	29	91	29°47'10"	81°15'29"	24.8	-	26.0	-	-
10	29	91	29°37'36"	81°11'47"	24.0	-	26.0	-	-
10	31	91	30°37'32"	81°21'22"	-	-	-	-	-
10	31	91	30°37'30"	81°21'19"	22.3	22.2	27.0	27.5	-
10	31	91	30°37'48"	81°21'46"	-	23.0	27.0	27.0	14.3
10	31	91	29°30'46"	81°08'39"	24.0	-	-	-	-
10	31	91	29°23'00"	81°05'01"	24.5	-	-	-	-
10	31	91	29°18'58"	81°03'07"	24.5	-	-	-	-
11	1	91	29°23'00"	81°05'01"	24.5	-	-	-	-
11	1	91	29°28'43"	81°07'38"	25.0	-	-	-	-
11	5	91	30°42'33"	81°25'10"	18.0	19.0	27.0	27.0	-
11	6	91	30°42'02"	81°25'38"	-	-	-	-	-

Appendix I (cont.). Water temperatures and salinities collected throughout the study period.

MONTH	DAY	YEAR	LATITUDE	LONGITUDE	SURFACE TEMP (°C)	BOTTOM TEMP (°C)	SURFACE SALINITY(PPT)	BOTTOM SALINITY (PPT)	DEPTH (M)
11	9	91	30°33'19"	81°26'39"	16.0	-	26.5	-	-
11	9	91	30°23'47"	81°23'36"	18.0	-	25.5	-	-
11	10	91	30°23'38"	81°23'45"	16.0	-	26.0	-	-
11	11	91	30°18'08"	81°20'27"	17.0	-	-	-	-
11	11	91	30°12'43"	81°16'42"	18.0	18.0	28.5	27.0	16.5
11	12	91	30°09'59"	81°14'56"	18.0	18.0	28.0	25.0	16.8
11	12	91	30°09'50"	81°14'55"	17.0	17.0	27.0	28.0	16.2
11	13	91	30°09'39"	81°21'24"	-	-	-	-	-
11	14	91	30°07'04"	81°11'53"	19.0	19.0	30.0	28.0	17.7
11	2	91	29°26'04"	81°06'26"	24.5	-	-	-	-
11	2	91	29°28'43"	81°07'38"	25.0	-	-	-	-
11	2	91	29°36'58"	81°11'30"	24.5	-	-	-	-
11	3	91	29°36'17"	81°11'14"	22.0	-	-	-	-
11	3	91	29°41'44"	81°13'25"	23.0	-	-	-	-
11	3	91	29°39'53"	81°12'43"	22.0	-	-	-	-
11	4	91	29°36'18"	81°11'12"	20.5	-	-	-	-
11	5	91	29°39'53"	81°12'43"	-	-	-	-	-
11	5	91	29°31'51"	81°09'12"	20.5	-	-	-	-
11	5	91	29°27'28"	81°07'02"	21.0	-	-	-	-
11	5	91	29°23'00"	81°05'01"	21.0	-	-	-	-
11	5	91	29°18'00"	81°02'39"	21.0	-	-	-	-
11	6	91	29°39'54"	81°12'44"	-	-	-	-	-
11	6	91	29°19'47"	81°03'31"	-	-	-	-	-
11	7	91	29°54'58"	81°17'28"	20.0	-	-	-	-
11	2	81	29°30'46"	81°08'39"	-	-	-	-	-